Gara Villalba
UC Merced visiting researcher

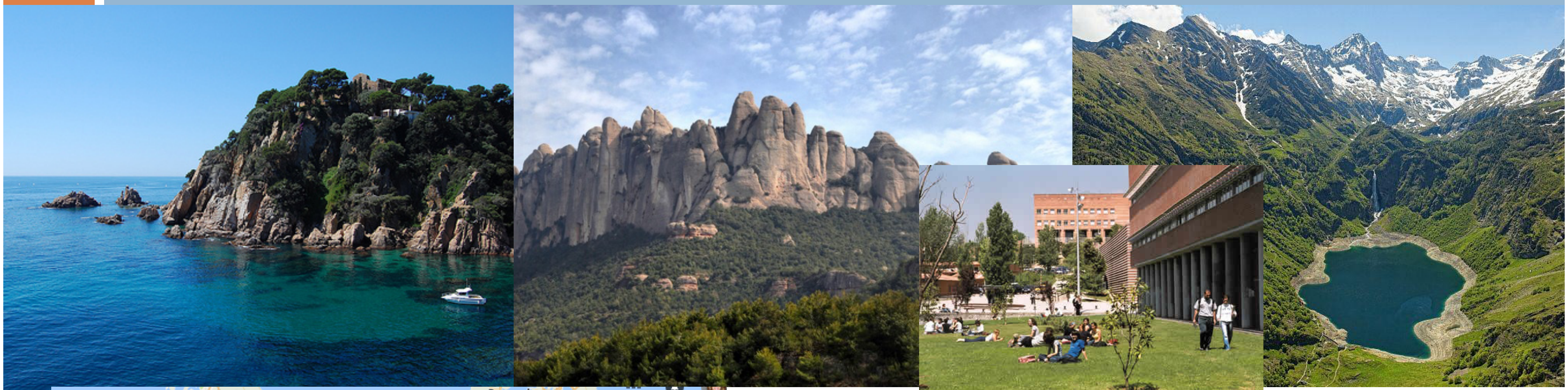
Simulation of Carbonyl Sulfide (COS) to better understand the urban biosphere signal

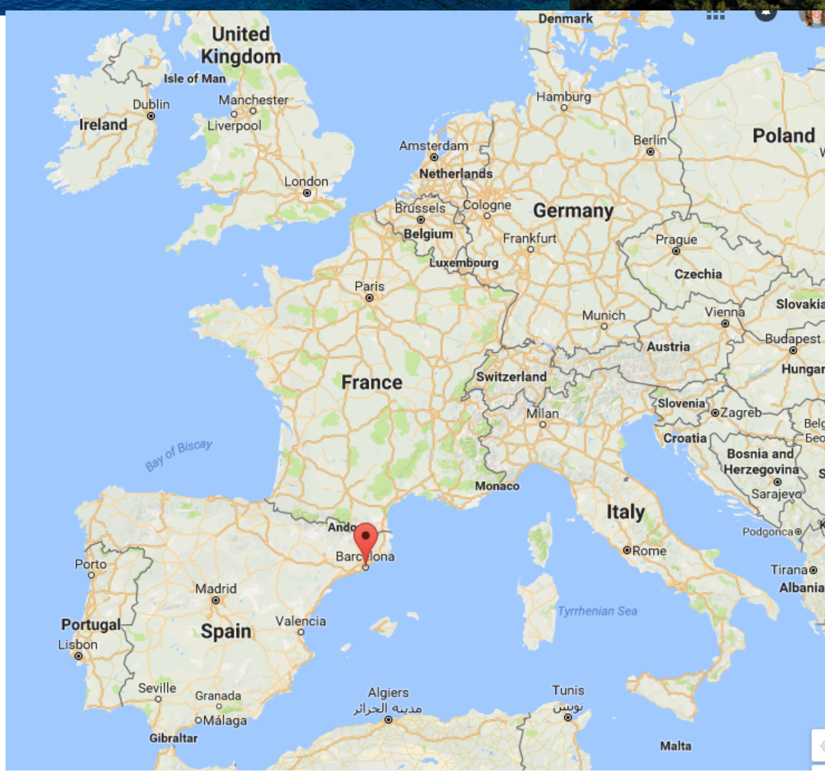
funded by EC Horizon 2020 Marie Sklodowska Curie Outgoing Fellowship

UC Merced Environmental Systems seminar

April 5th, 2017

From Autonomous University of Barcelona (UAB)





Istitute of Environmental Science and Technology (ICTA)

Department of Chemical, Biological and Environmental Engineering

Cities:

-70% of GDP

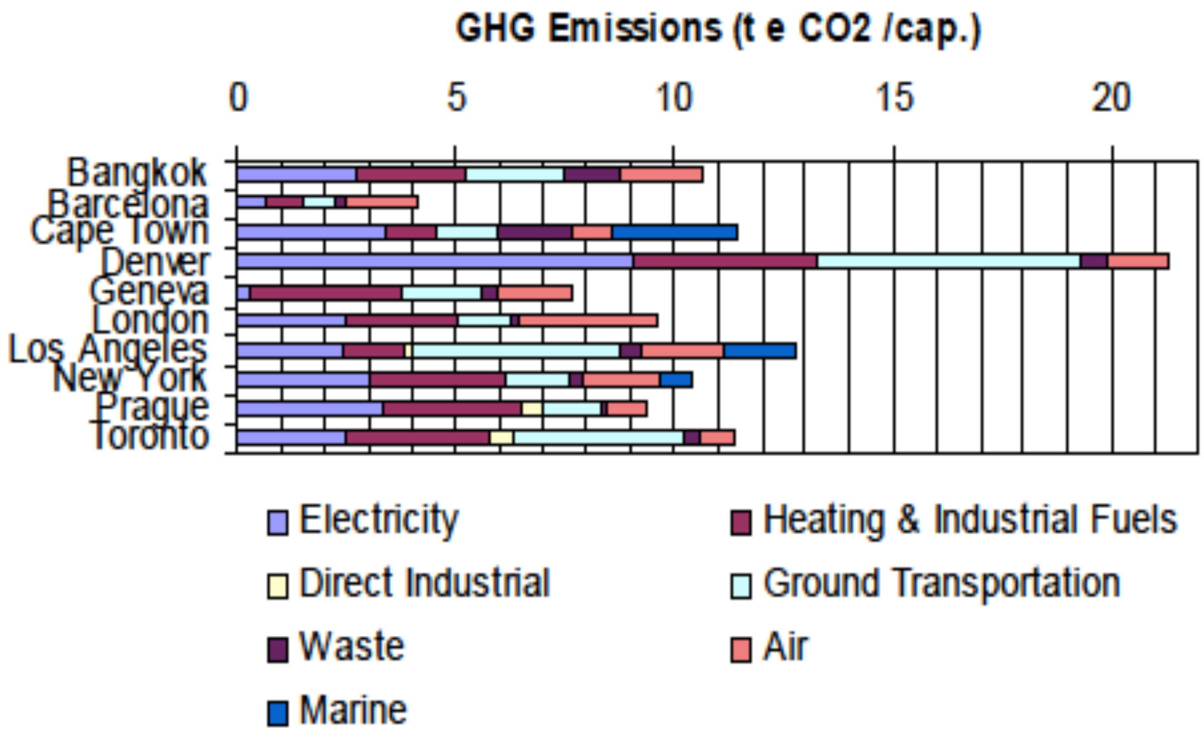
-50% global population

-by 2050: 70% world population, 75% energy consumption, 90% GHG emissions

-by 2050: urban areas ⇧2.5 to 4 °C

-key problems:

- -warming
- -water supply
- -pollution
- -extreme weather conditions
- -food supply
- -acidification of oceans



"Green house gas emissions from global cities." Environmental Science & Technology 2011, 43(19): 7297–7302.

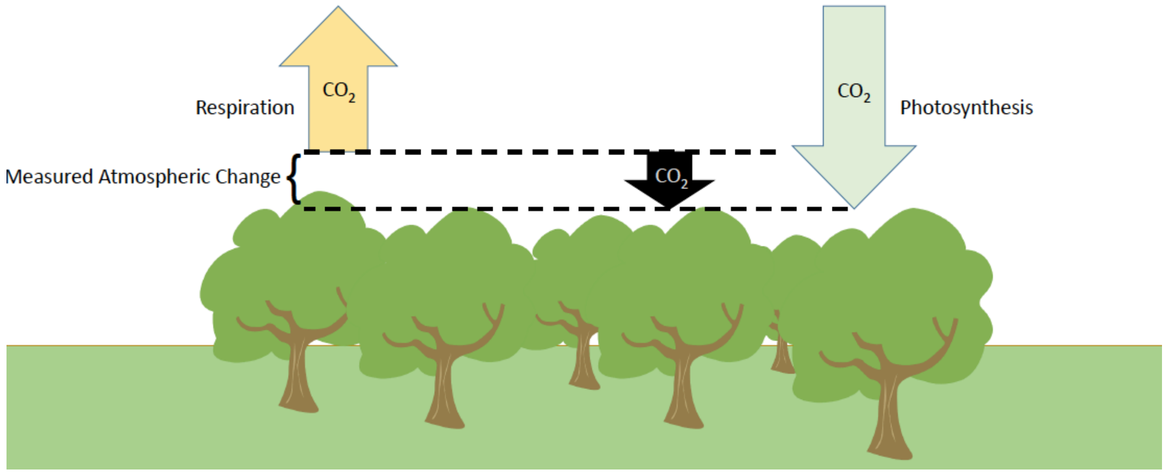
Limitations of bottom-up approaches:

- Difficult to include urban biosphere
- Time and resources
- Poor objectivity
- Many simplifications and assumptions, data quality
- Uncertainty of temporal scales

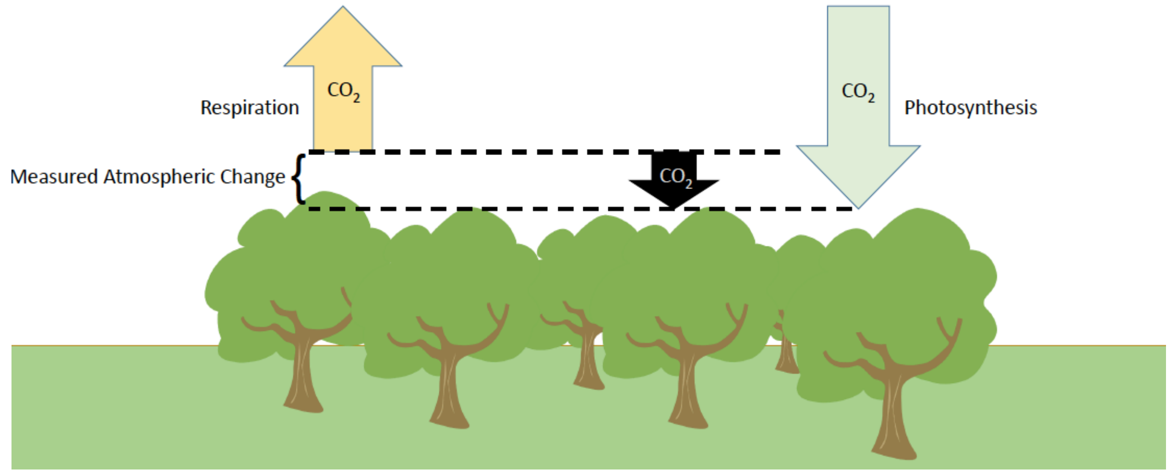
Atmospheric models and observations for improved GHG accounting

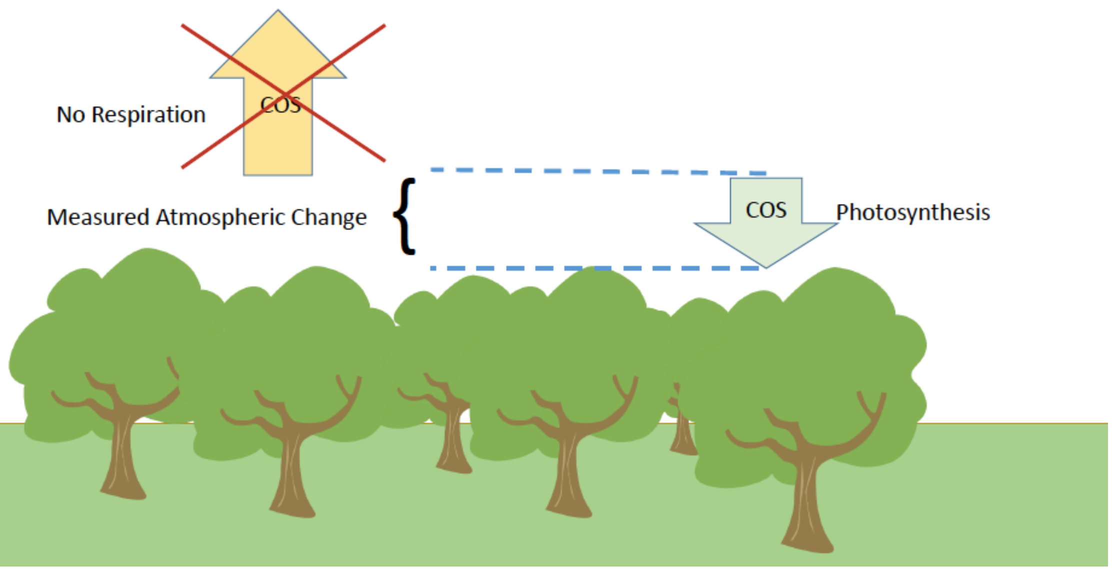
- To determine the effect of the urban biosphere
- Certainty and data quality analysis
- Resolves temporal scales
- Simulate how different types of land use affect urban carbon footprint.

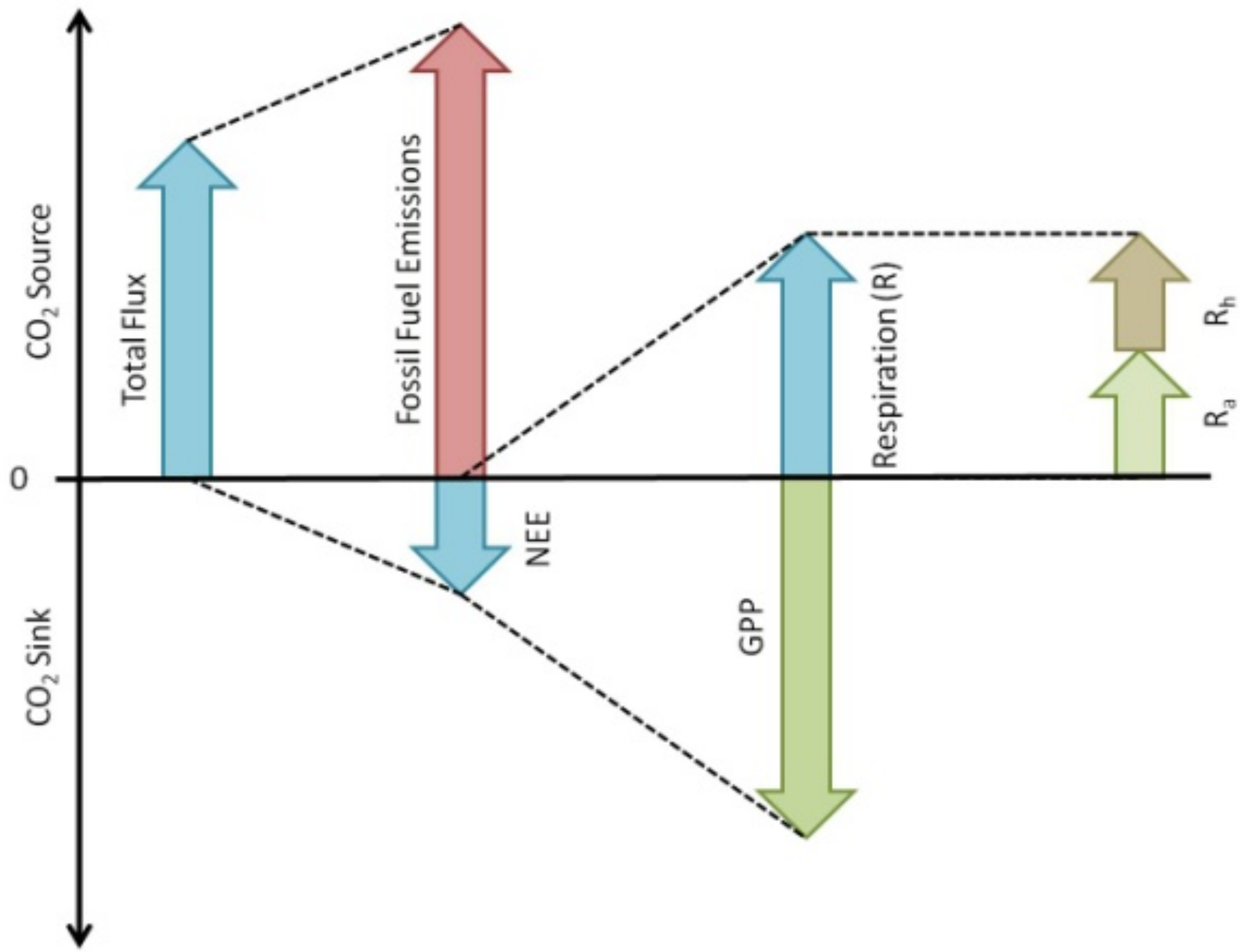
CO_2 captured via photosynthesis cannot be measured



COS as a tracer for CO_2 capture via photosynthesis

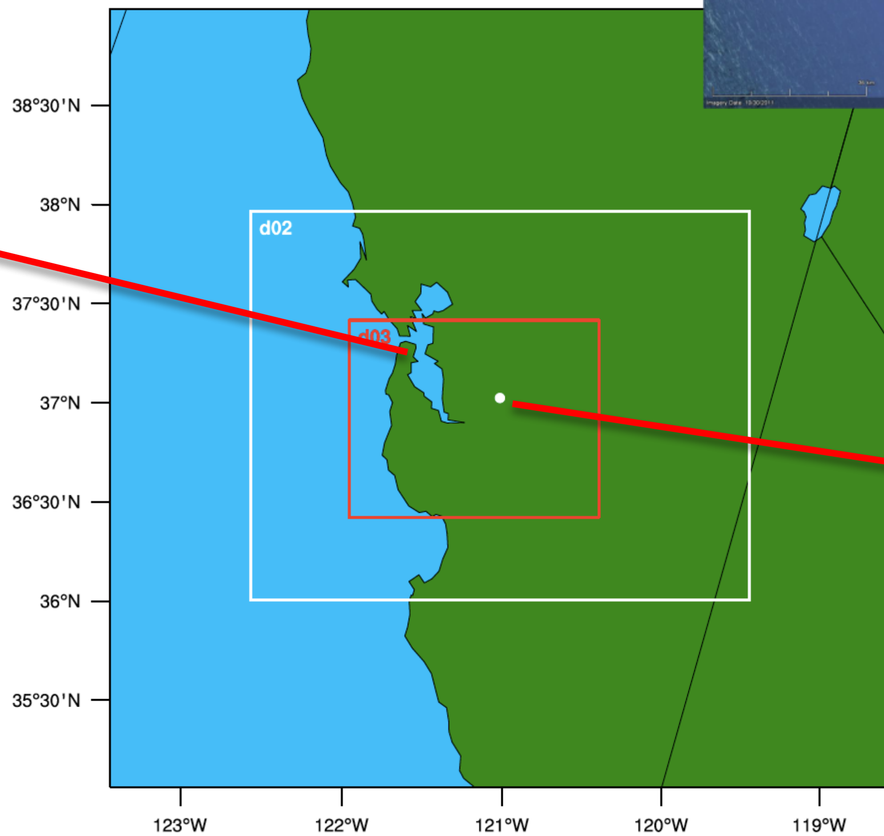


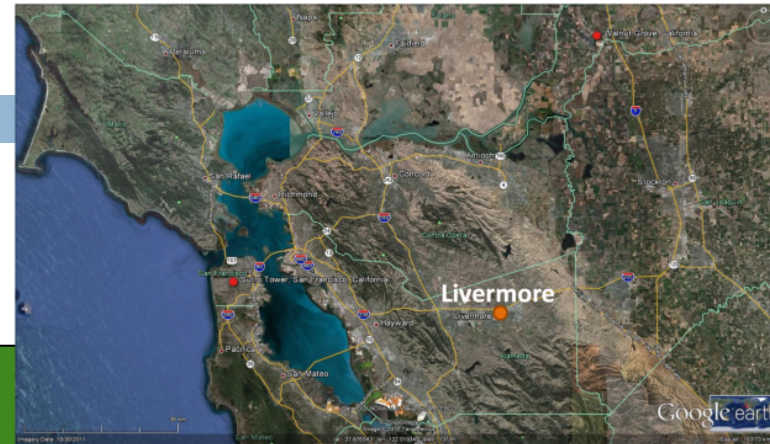



CO2 Source
Total Flux
Fossil Fuel Emissions
Respiration (R)
Rh
Ra
0
NEE
GPP
CO2 Sink

Case Study: March 5-25, 2015

Sutro Tower





City of Livermore
Sandia Tower of observation

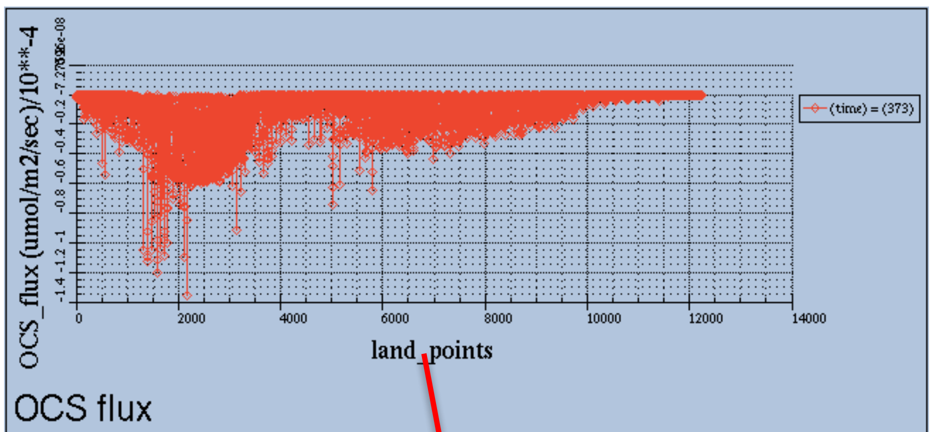
WRF ↘ STEM → COS concentrations
Biosphere models ↗

Biosphere models

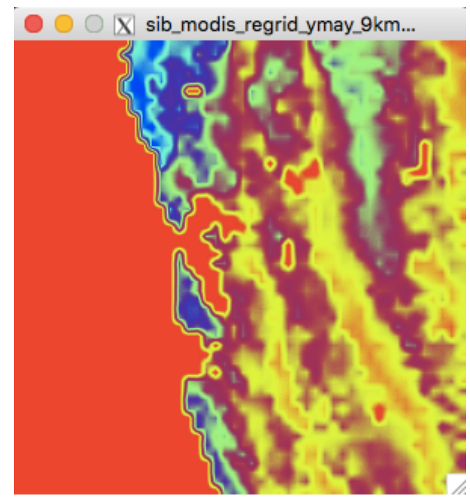
-resolutions of 1 by 1.25º

-need higher spatial resolution to determine biosphere signal in urbanized areas

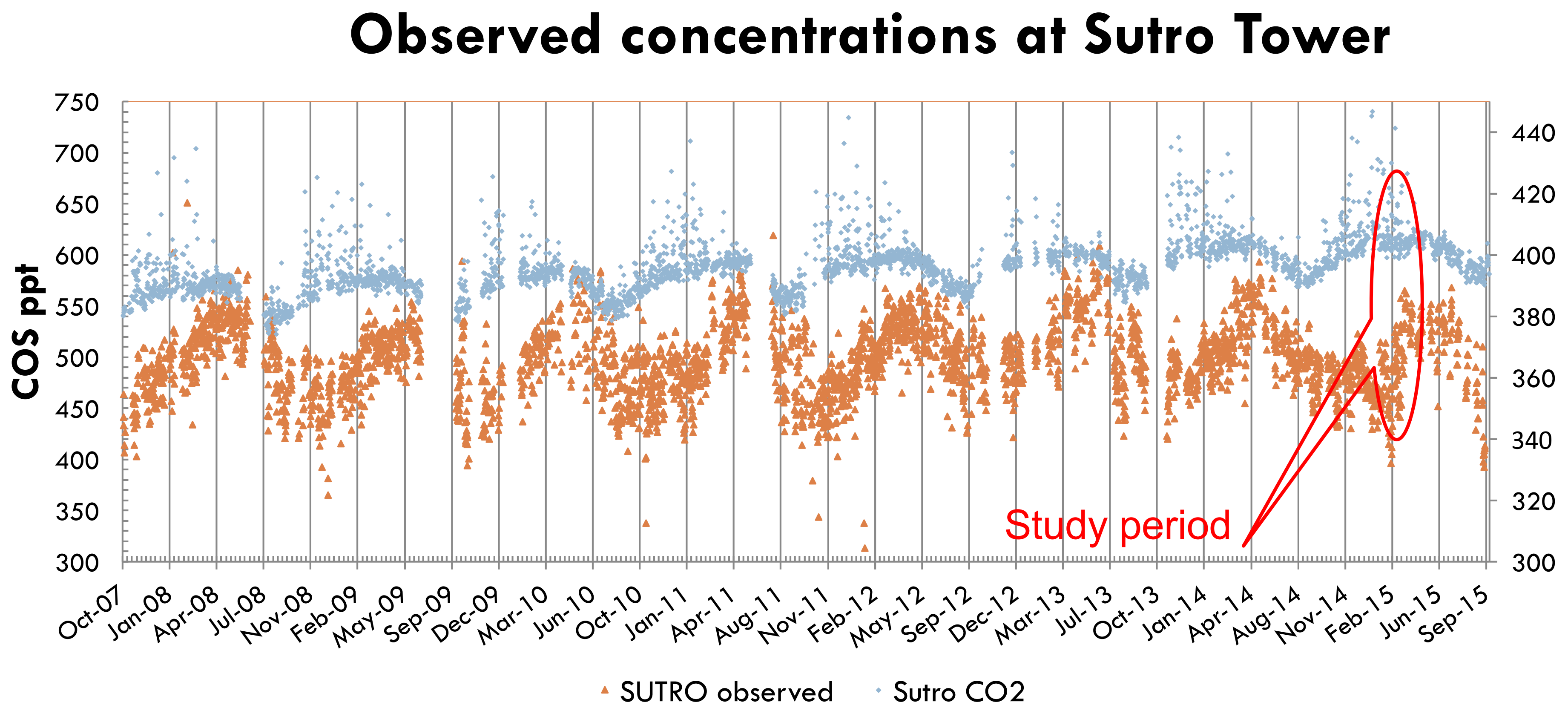
-achieve higher resolution by redistributing fluxes according to high resolution MODIS NDVI values



MODIS NDVI 1km or 250 m

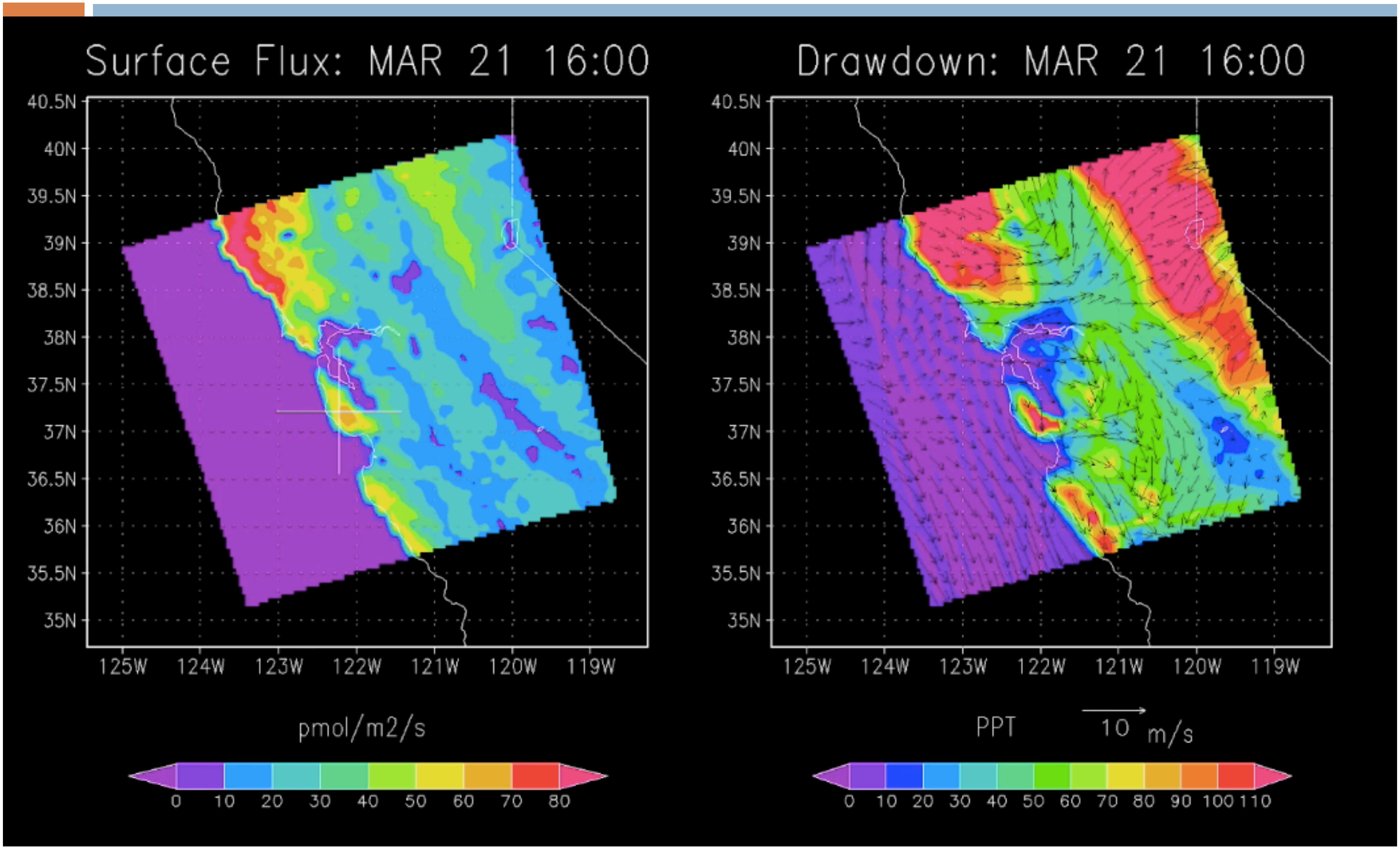


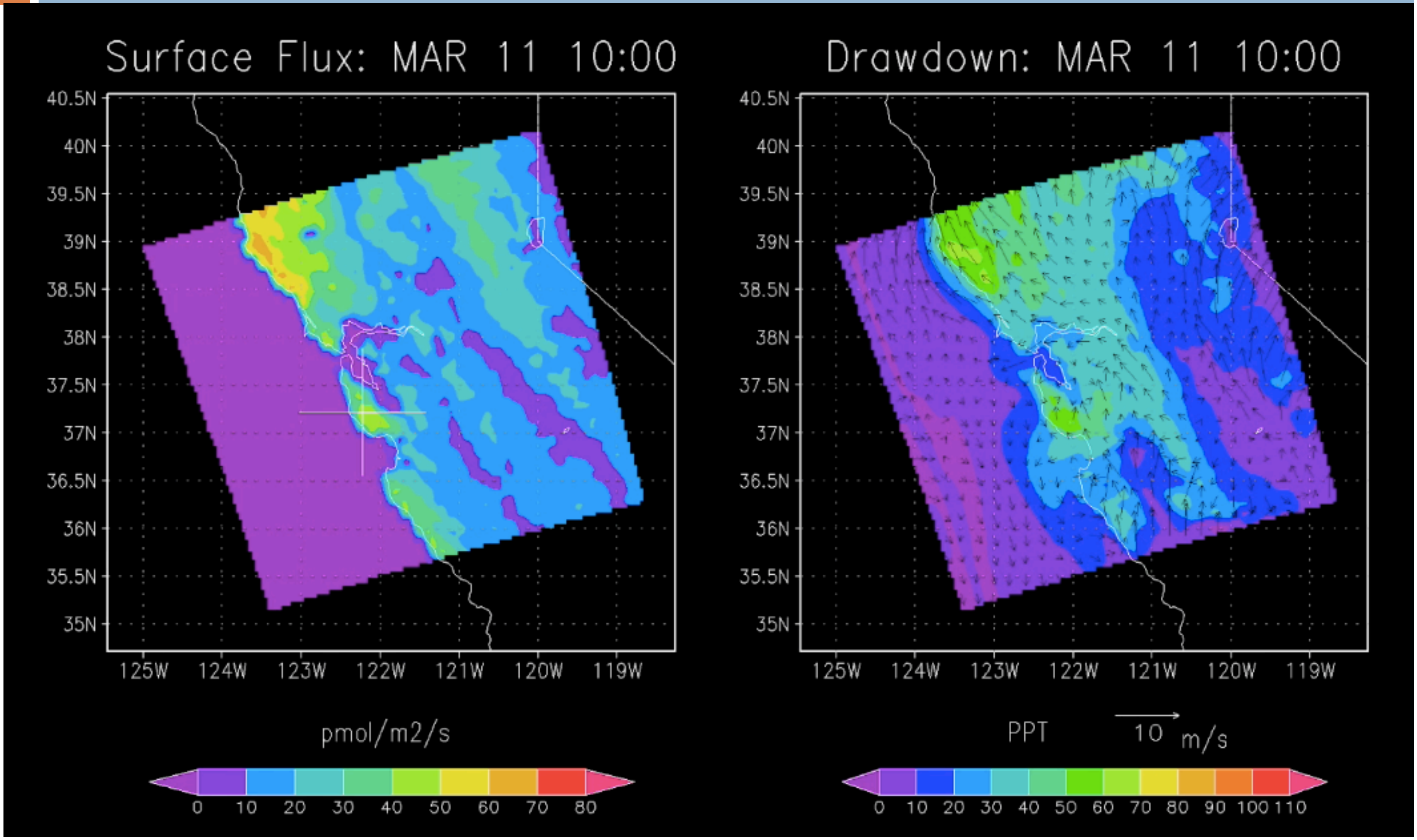
$$\underset{\text{(entire STEM domain)}}{SiB\ COS\ flux\ value} \times \frac{NDVI\ value\ for\ 1\ NDVI\ pixel}{NDVI\ value\ for\ entire\ STEM\ domain} = COS\ flux\ value\ for\ 1\ pixel$$

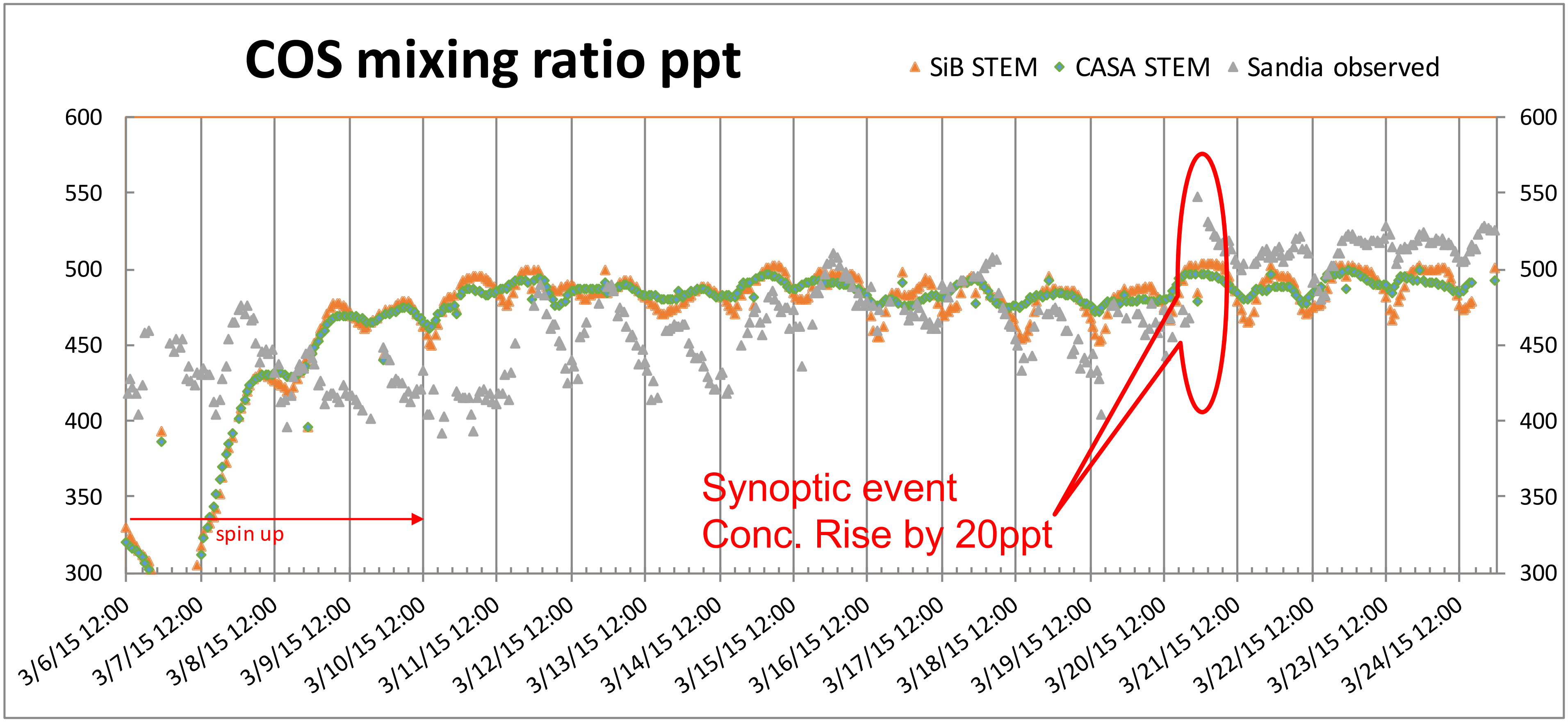


Seasonal variations are 10%, and synoptic variation can be 20%
Background COS and CO_2: 450ppt, 405 ppm, respectively.

Using STEM to determine COS mixing ratios



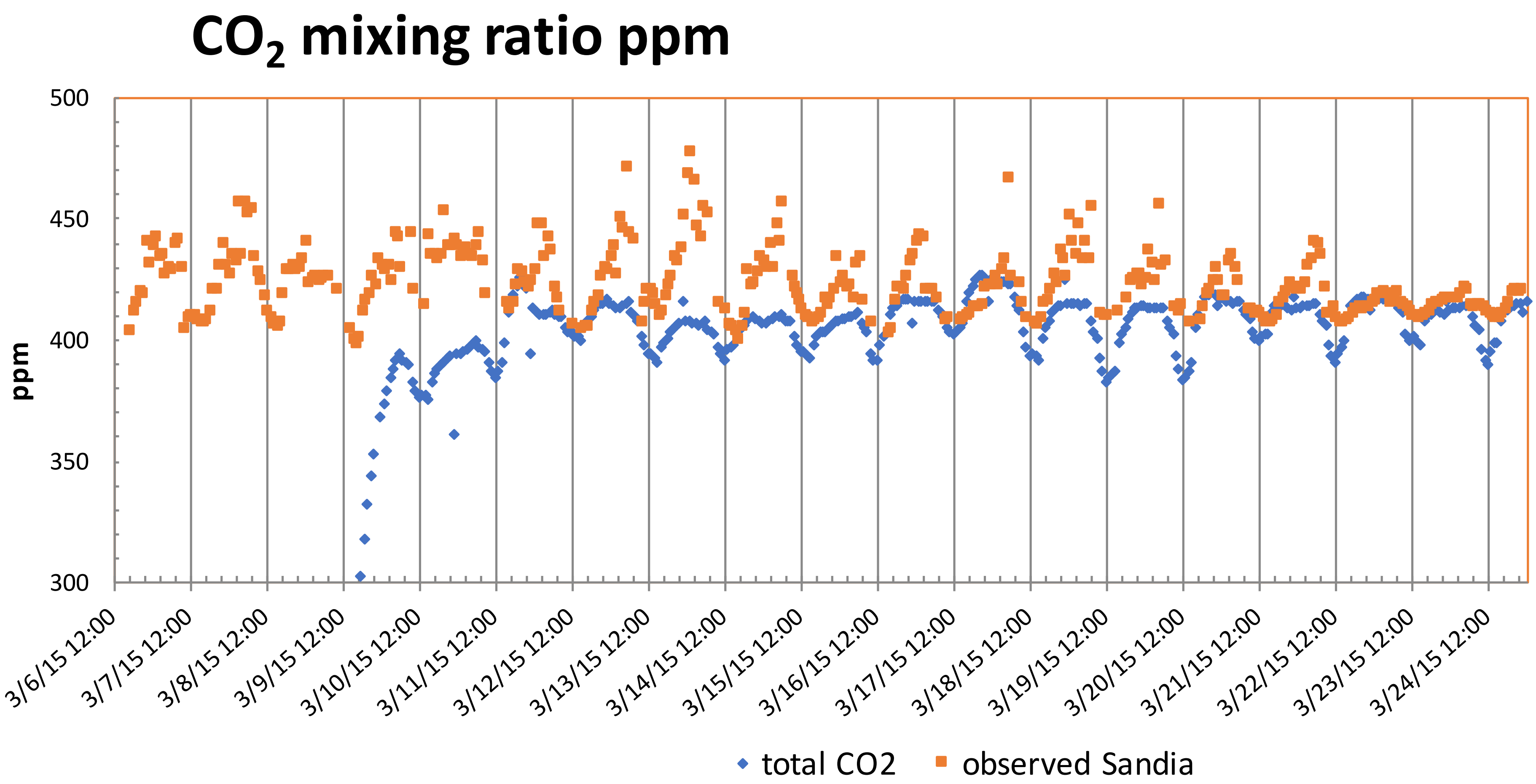

Surface Flux: MAR 11 10:00
Drawdown: MAR 11 10:00
40.5N
40N
39.5N
39N
38.5N
38N
37.5N
37N
36.5N
36N
35.5N
35N
125W 124W 123W 122W 121W 120W 119W
pmol/m2/s
0 10 20 30 40 50 60 70 80
PPT
10 m/s
0 10 20 30 40 50 60 70 80 90 100 110



COS ppt high at night and early am (up to 450 ppt), then start to drop late morning/noon, reaching lowest values (down to 220 ppt) around 3-4pm.

-Applying mass balance equation

$$TOTAL\ CO_2 = CO_{2\ background} + CO_{2\ respiration} + CO_{2\ fossil} - CO_{2\ GPP}$$



Fertile City
The Rooftop Greenhouse Lab:

optimizing food production in buildings through

integrated Rooftop Greenhouses in Barcelona, Spain



Pilot project: i-RTG-Lab (ICTA-UAB)

<u>Aims of the i-RTG-Lab:</u>

-Demonstrate the feasibility of producing food in i-RTGs in a Mediterranean context

-Characterize and quantify the potential exchange of flows between i-RTGs and buildings

“FertileCity” multidisciplinary team

icta

Environmentalists
Designers
Engineers

UPC

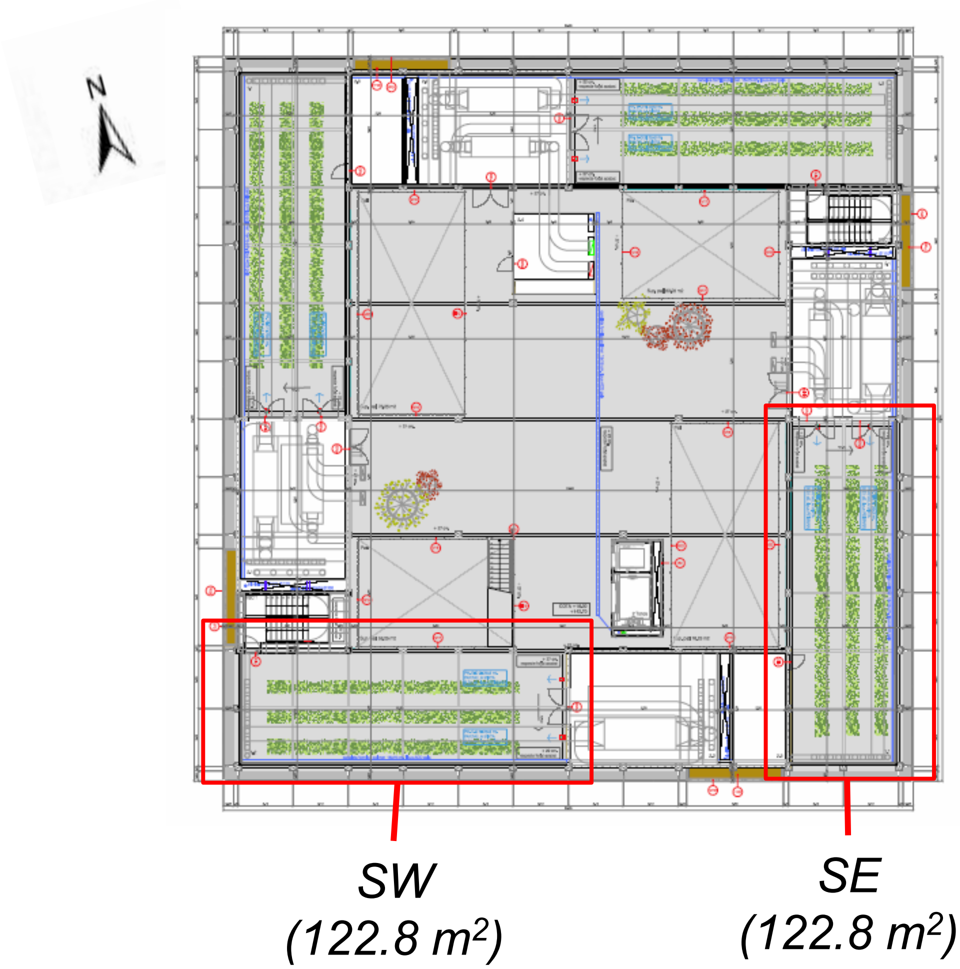
Architects
Engineers

IRTA
RECERCA I TECNOLOGIA AGROALIMENTÀRIES

Agronomists

Design of the i-RTG-Lab

Pilot project: i-RTG-Lab (ICTA-UAB)



2 i-RTGs (122.8m^2 each)

Interconnection with the building:

-Energy

-Water

-Gas

Design of the i-RTG-Lab

Soil-less culture system

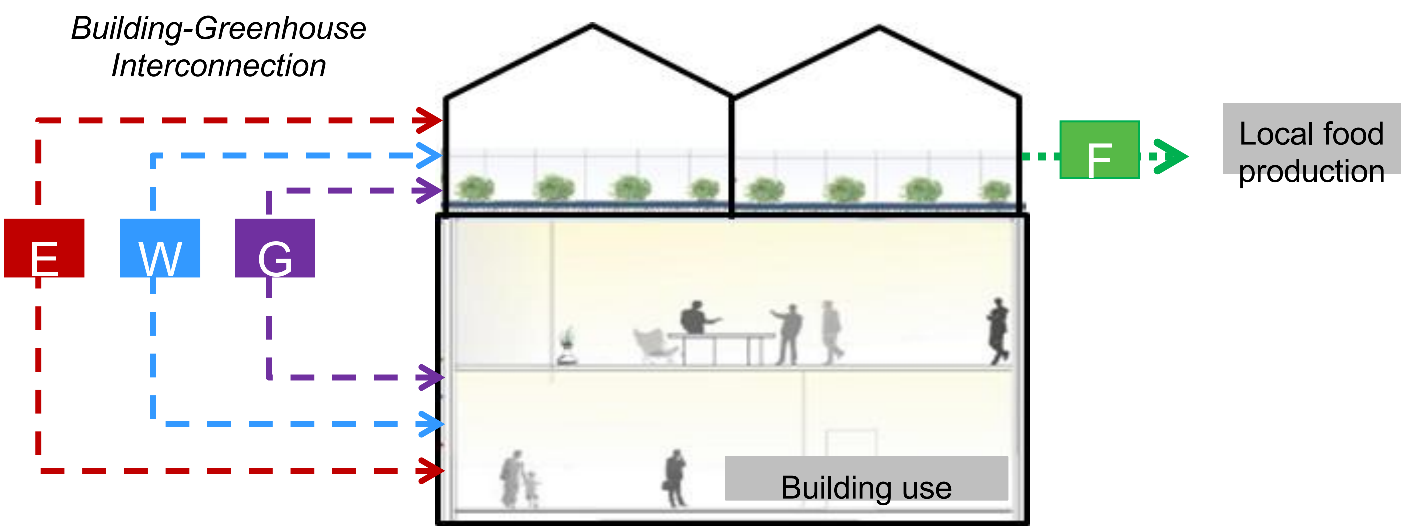
Substrate: perlite

Automatic irrigation with NPK

Crops: lettuce, tomato

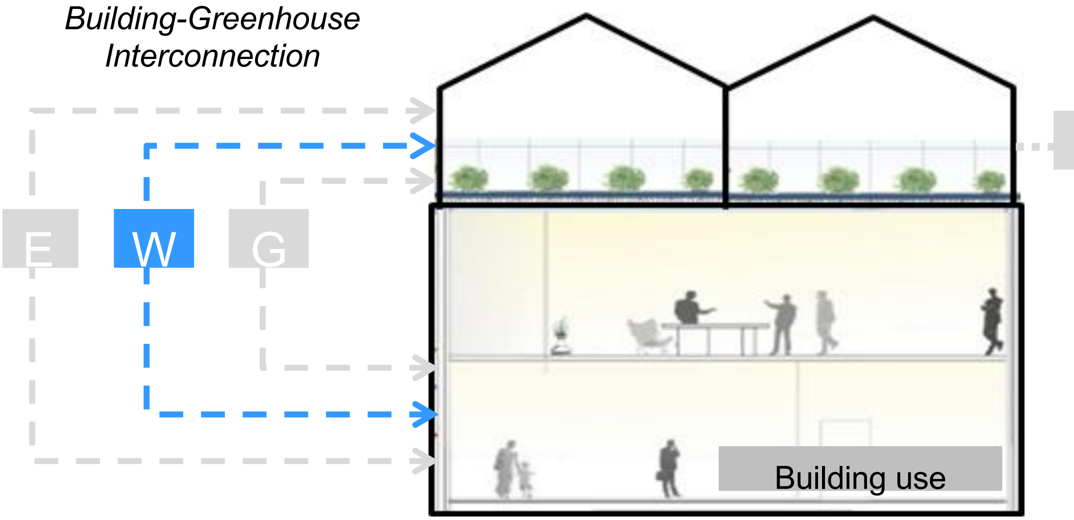
i-RTG-Building interconnection

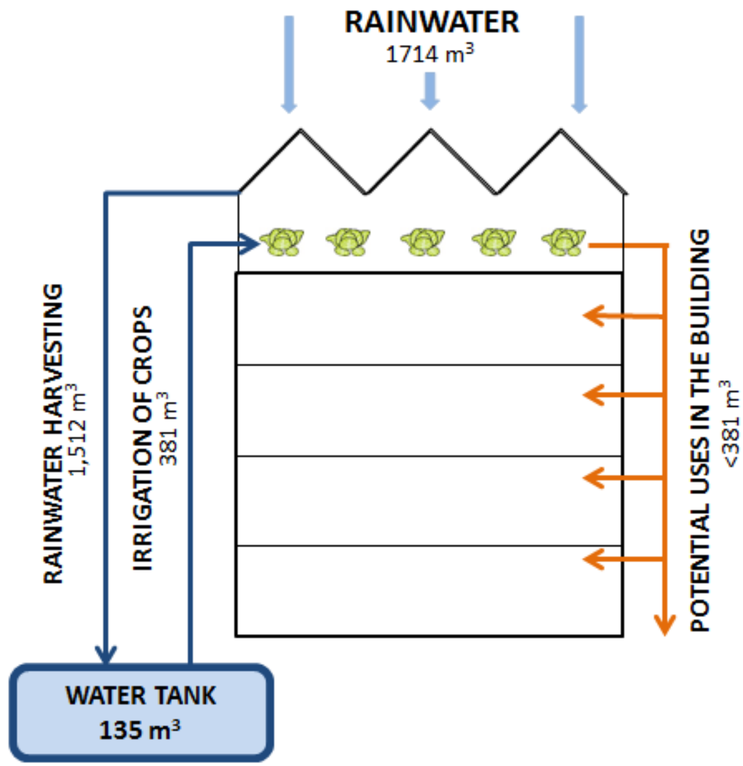
The RTG-building interconnection aims to reduce the environmental Impact of the local food production by optimizing the energy, water and gas flows



i-RTG-Building interconnection

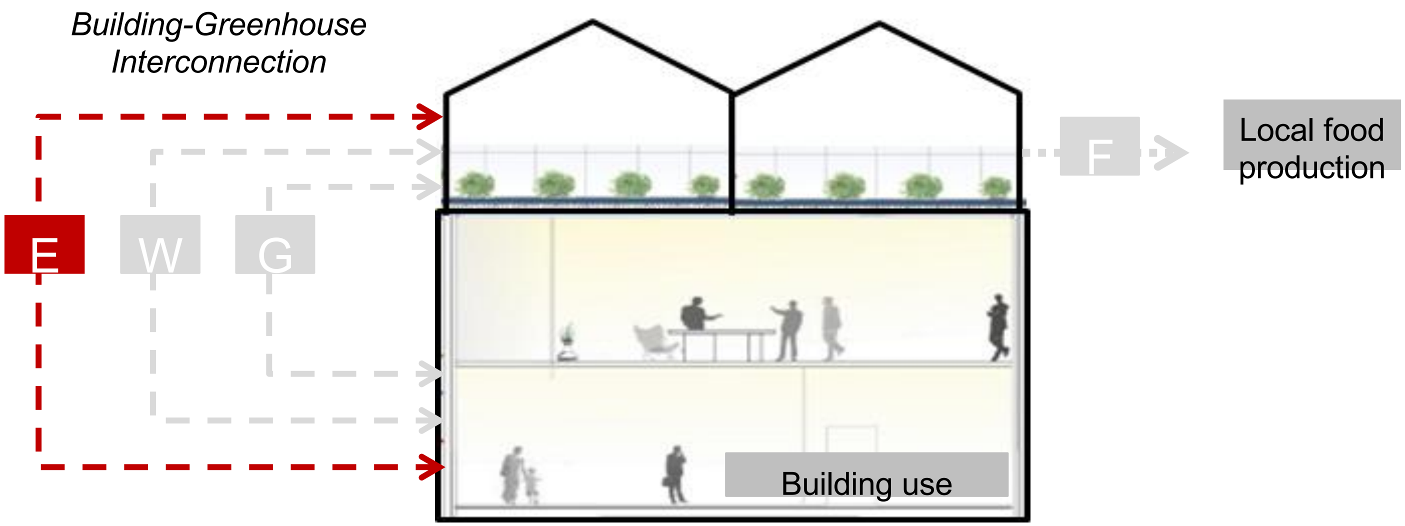
Exchange of water flow



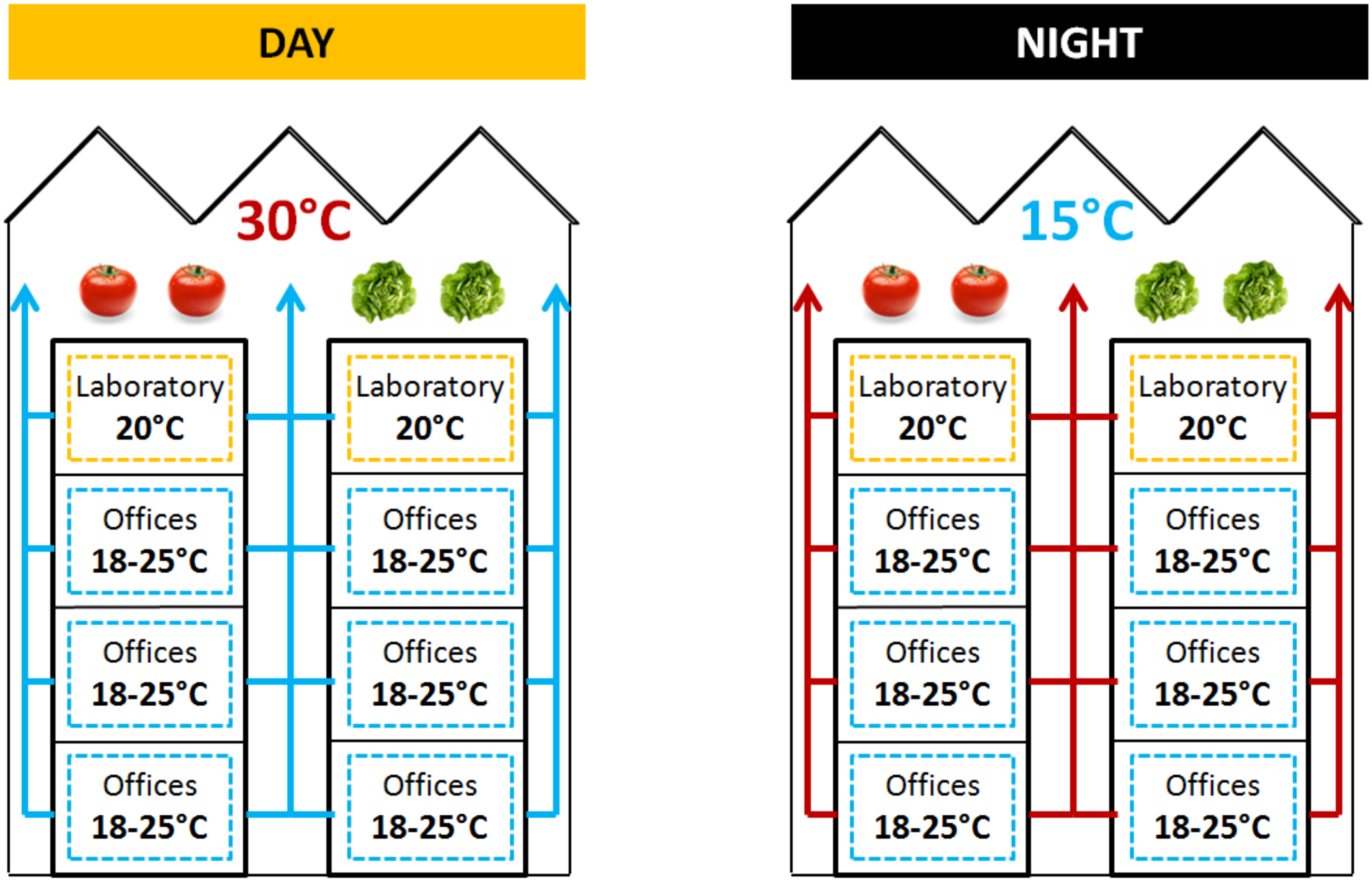


i-RTG-Building interconnection

Exchange of energy flow

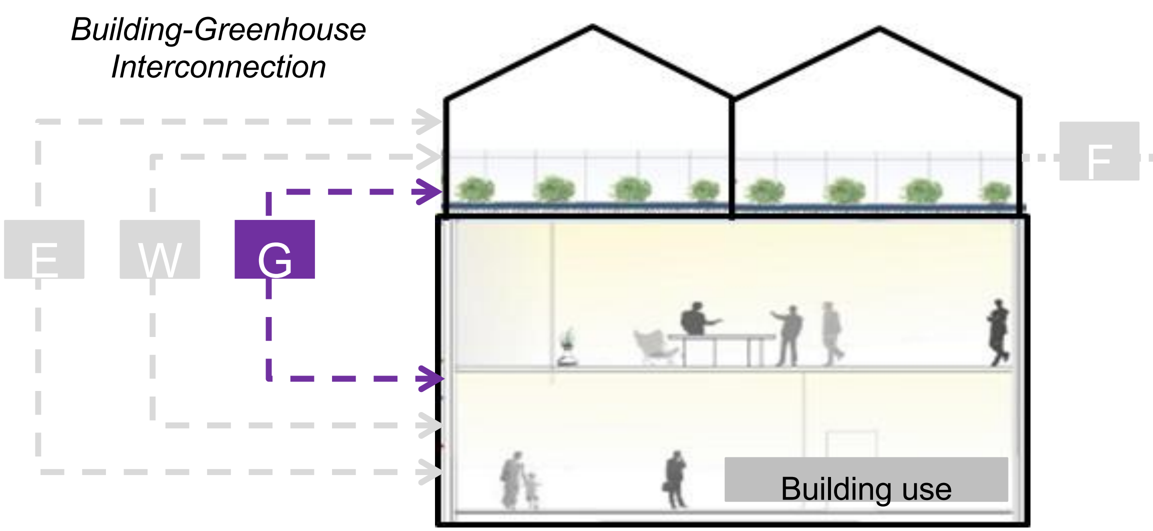


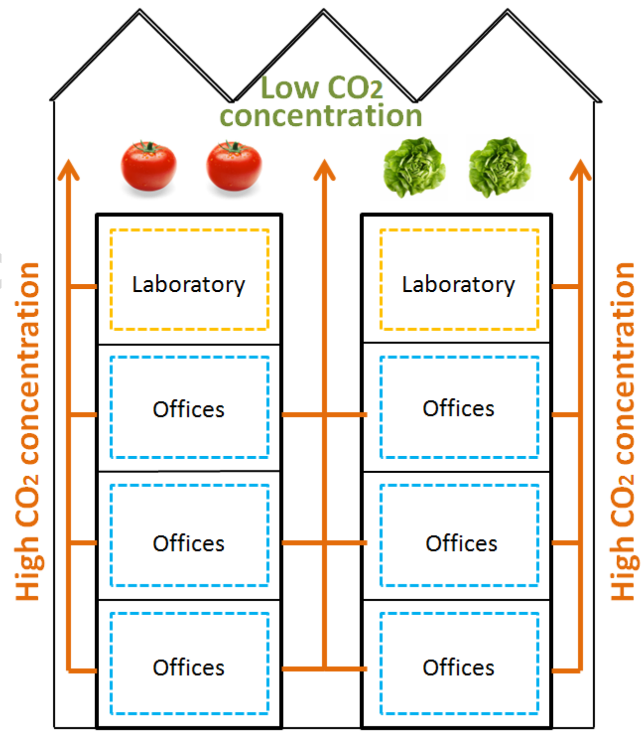
Exchange of energy flow



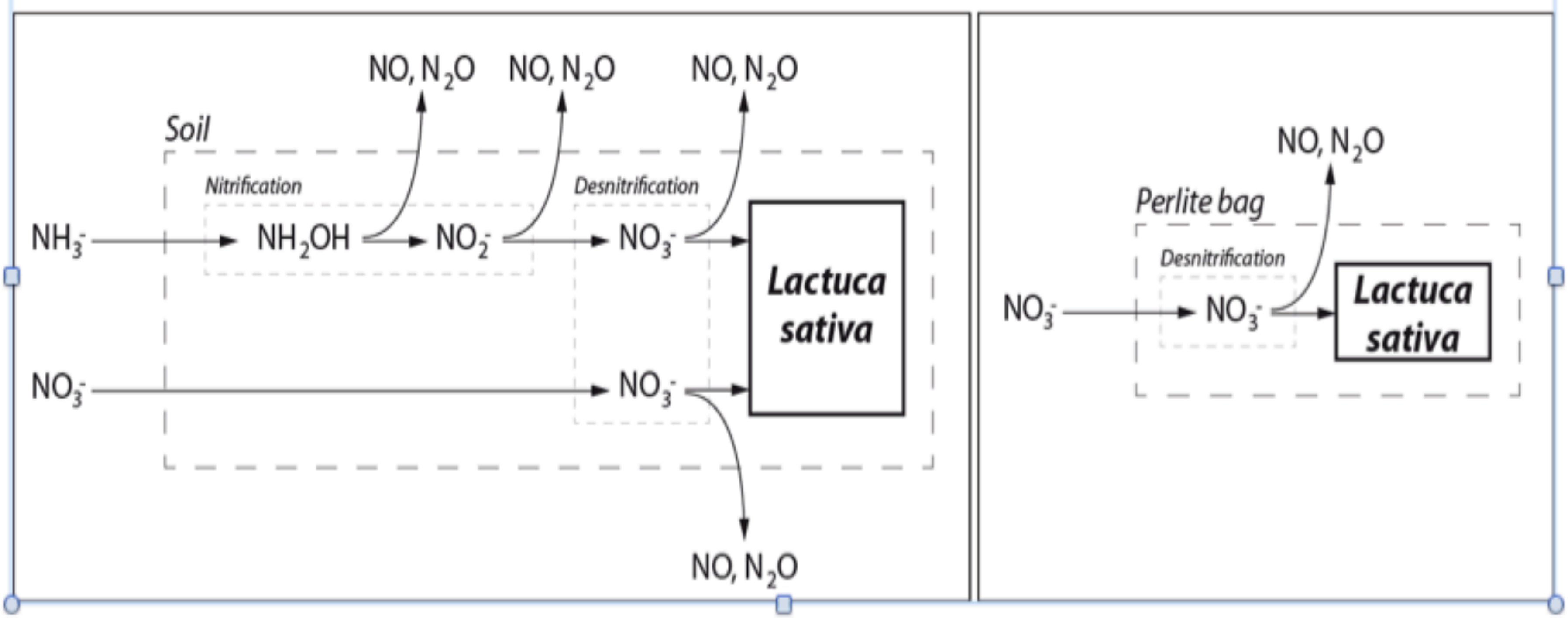
i-RTG-Building interconnection

Exchange of gas flow





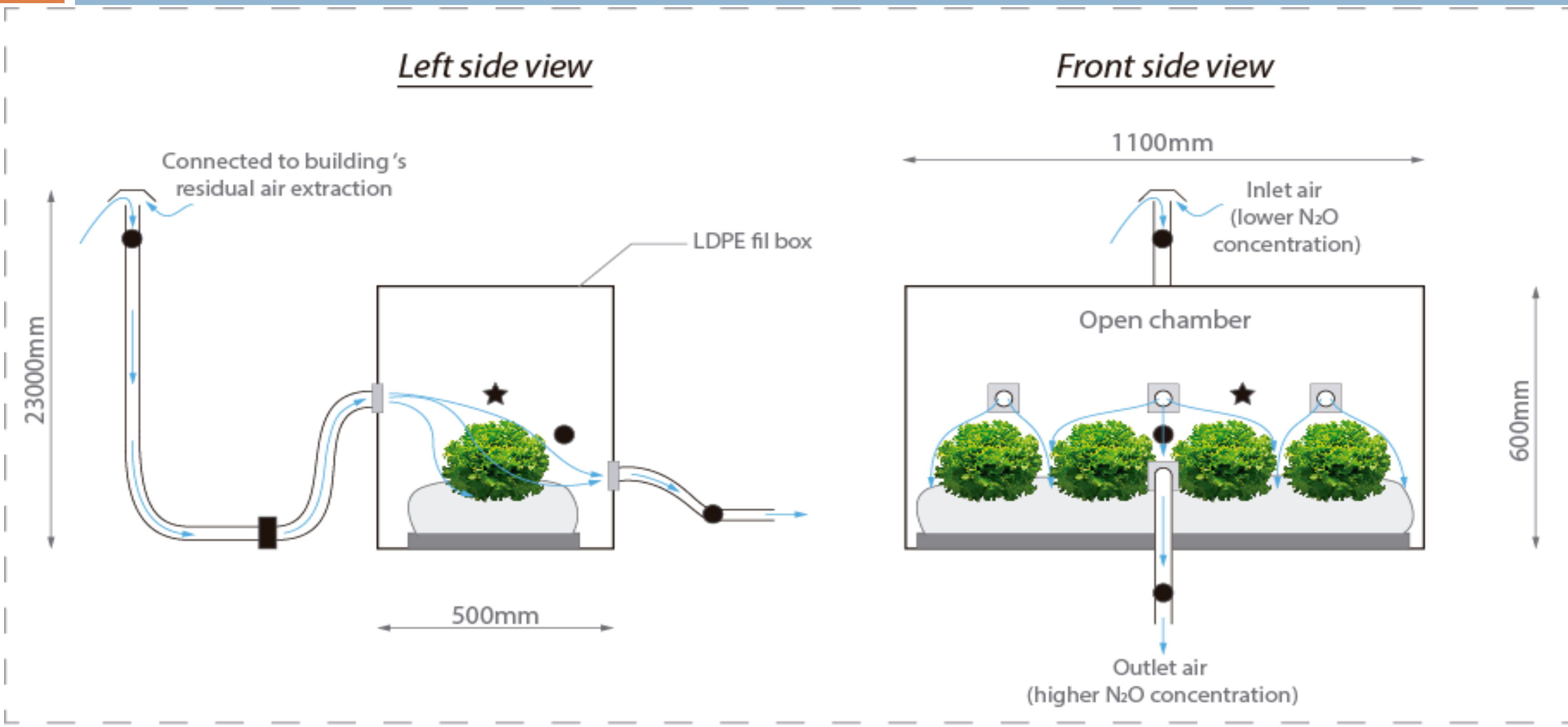
Objective: quantify CO_2 capture and N_2O emissions in GRT.



Nitrification and denitrification reactions in soil.

Only denitrification reaction in soil-less substrate.

How? **Methods: Open Chamber Design**

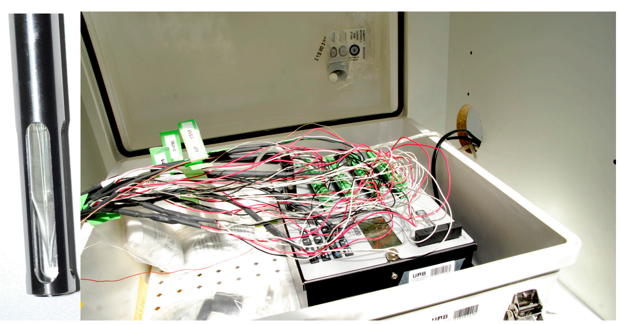


★ Unisense Clark-Type microelectrode N_2O sensor

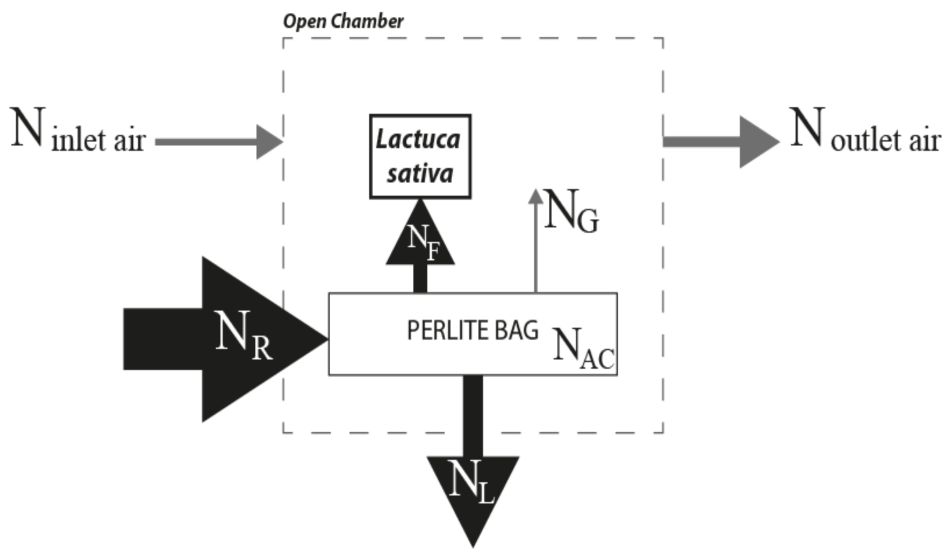
● Points of air sampling to analyze N_2O with the GC

▮ Blower

○ Fresh air inlets



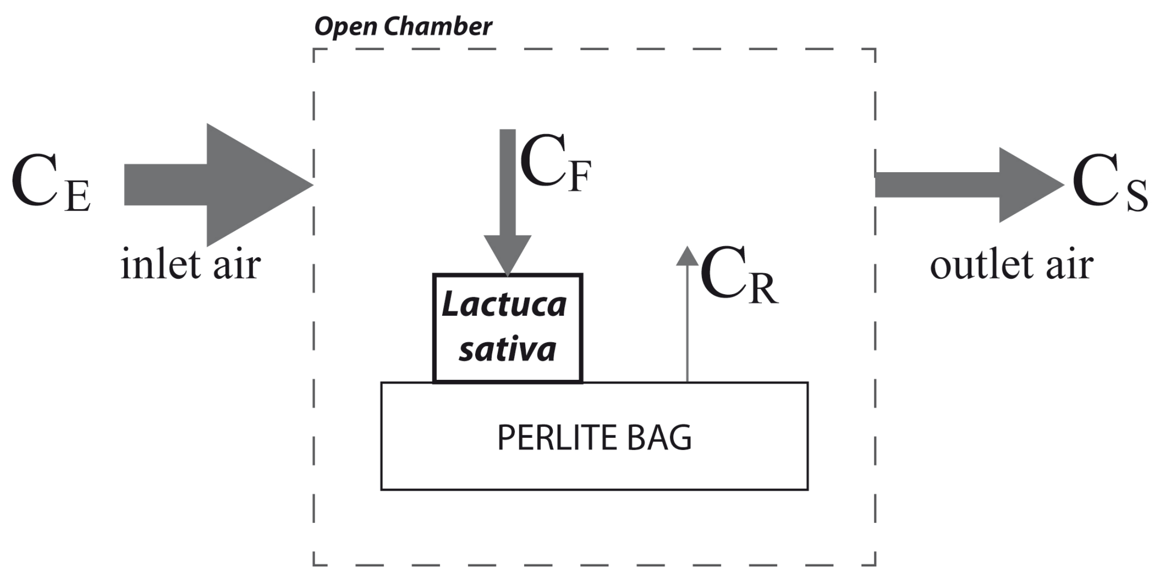
N balance



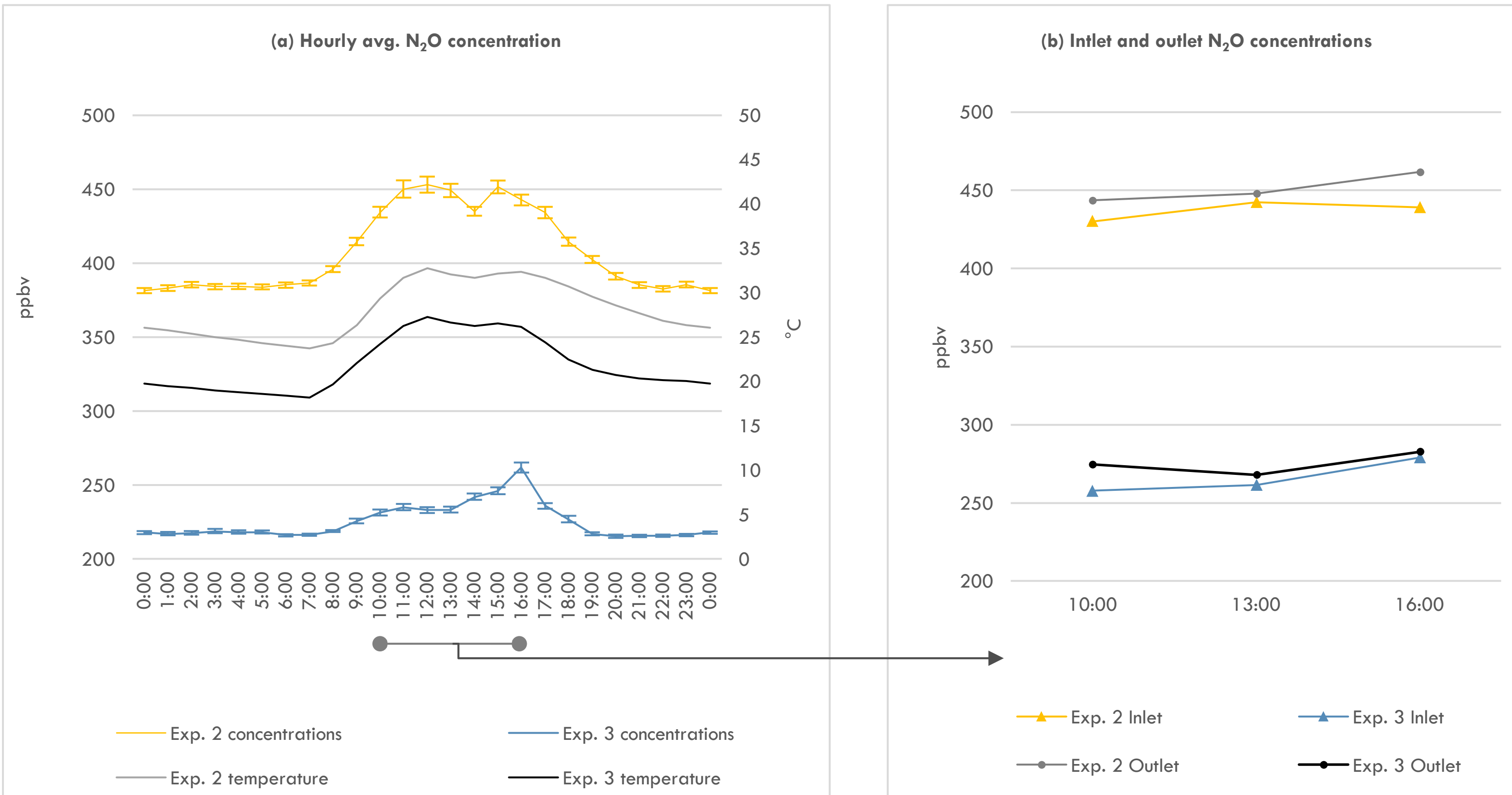
$$N_R = N_L + N_F + N_G + N_{Ac}$$

$$N_G = N_{outlet\ air} - N_{inlet\ air}$$

C balance

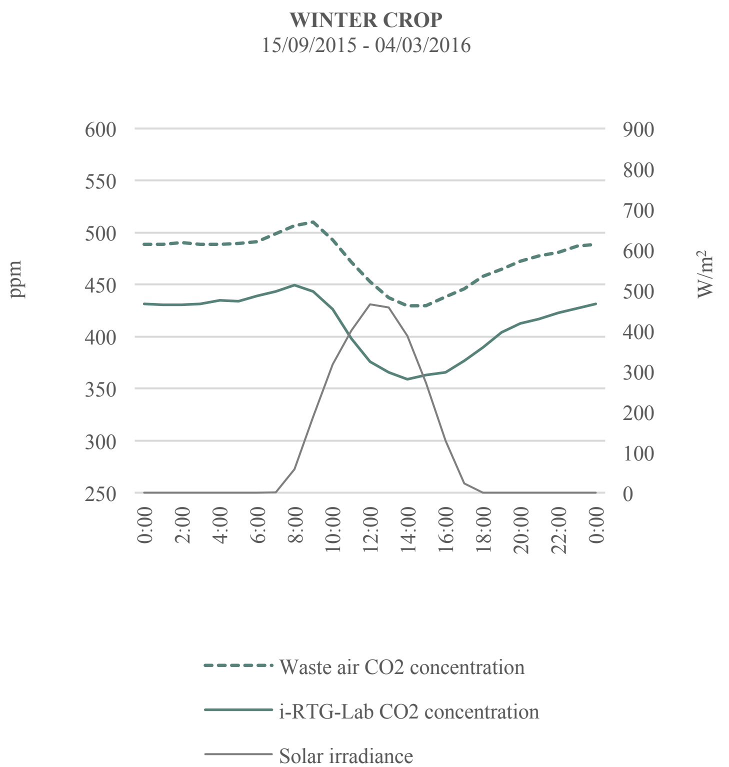


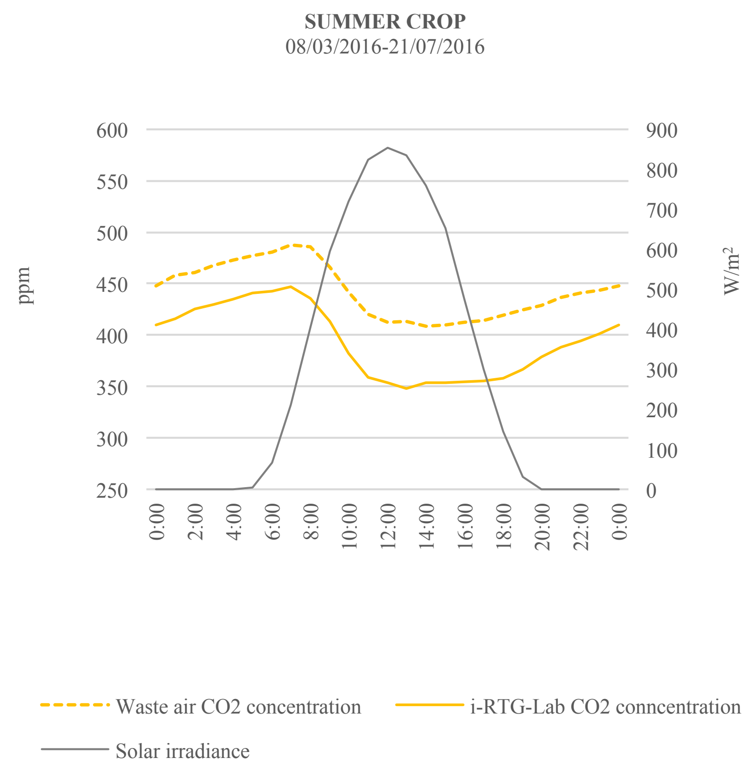
$$C_E = C_R + C_F + C_S$$



N_2O emissions from protected soil-less crops for more precise food and urban agriculture life cycle assessments. Journal of Cleaner Production, (2017) 49:15,1118–1126.

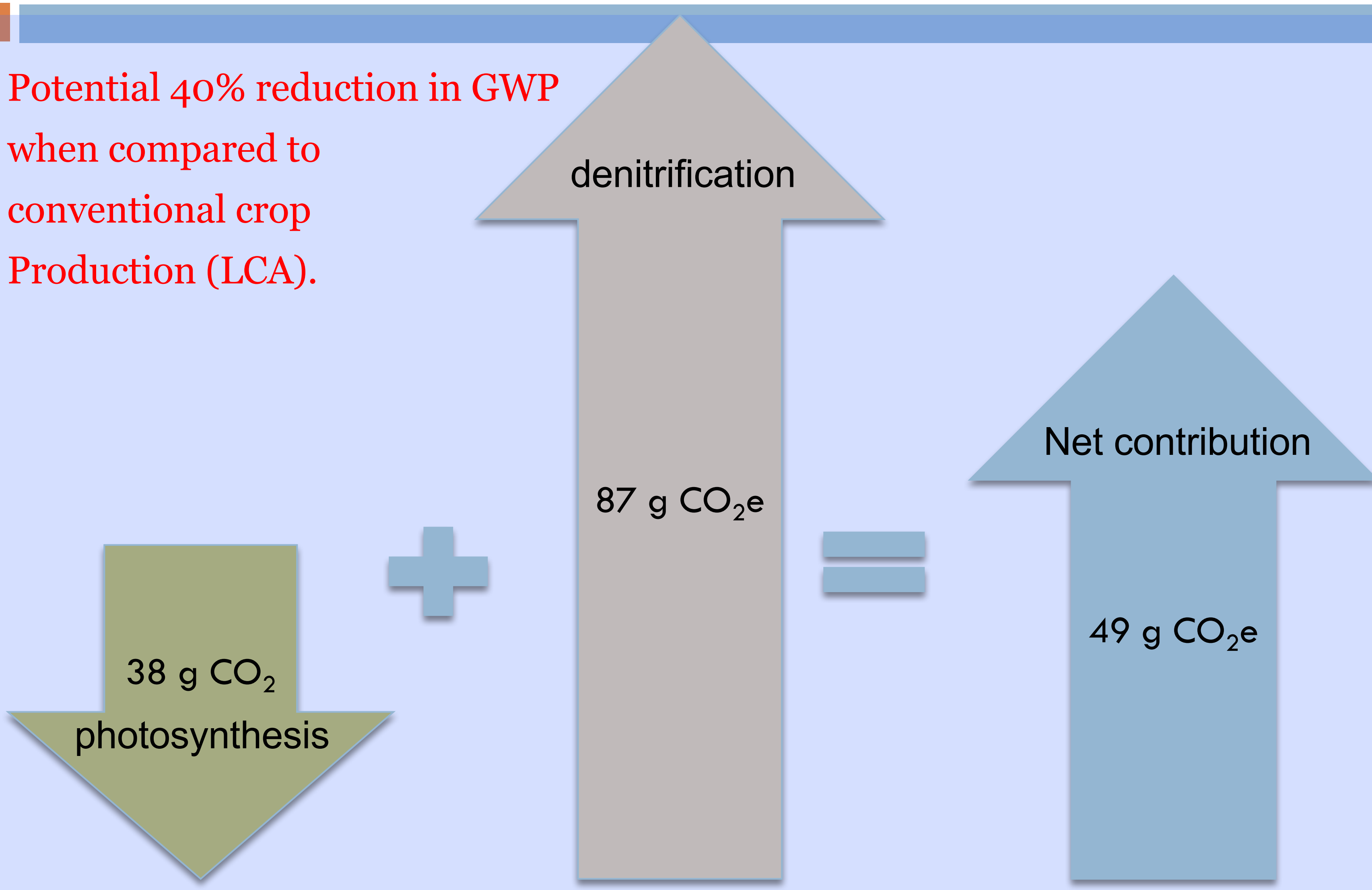
EF: 75 g N_2O per kg N (roughly half the EF provided by the IPCC (0.0125 kg N_2O per kg N)


WINTER CROP
15/09/2015 - 04/03/2016
600
550
500
450
400
350
300
250
ppm
900
800
700
600
500
400
300
200
100
0
W/m2
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Waste air CO2 concentration
i-RTG-Lab CO2 concentration
Solar irradiance


SUMMER CROP
08/03/2016-21/07/2016
600
550
500
450
400
350
300
250
ppm
900
800
700
600
500
400
300
200
100
0
W/m2
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Waste air CO2 concentration
i-RTG-Lab CO2 conncentration
Solar irradiance

Results

Potential 40% reduction in GWP when compared to conventional crop Production (LCA).



BENEFITS: ENVIRONMENT

i-RTGs will promote local food products with a **lower environmental impact**:

- Increase in crop yield
- Decrease in energy consumption
- Decrease in water demand
- Decrease mineral fertilizer use
- Decrease in distribution requirements

BENEFITS: SOCIETY

Accessibility to **healthy food products**

Community development: local bussinesses

Traceability of food products

More liveable buildings

BENEFITS: ECONOMY

Decrease in food **costs** (i.e., production, transport)

Dinamization of **local economies**

Reduction in **use costs of buildings**

Thank you!