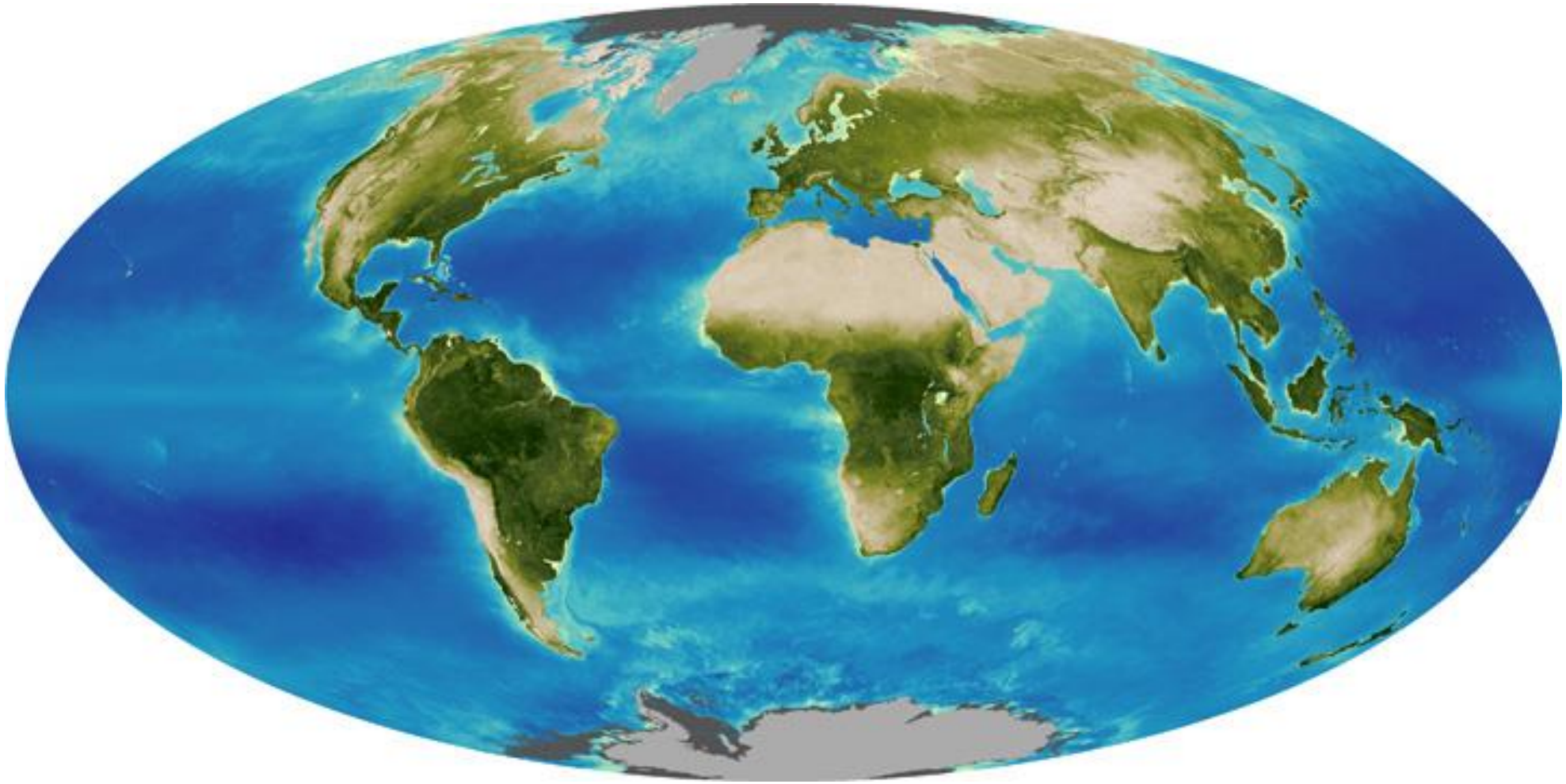

全球气候变化及不同空间尺度碳循环研究方法

Liukang Xu

LI-COR

LI-COR Connect 2025

February 24–27, 2025

Tucson, Arizona, USA

Register

Already registered?

Topics

- Evidences: Global warming and climate change
- Ecosystem response to climate change and global warming
  - FACE
  - Warming
  - Precipitation manipulation
- Carbon cycle study
  - GAW
  - GHG and energy flux measurement (leaf level, soil surface, ecosystem level)
  - Remote sensing (SIF)
  - Isotope
- Mitigation strategies

Climate change in daily news

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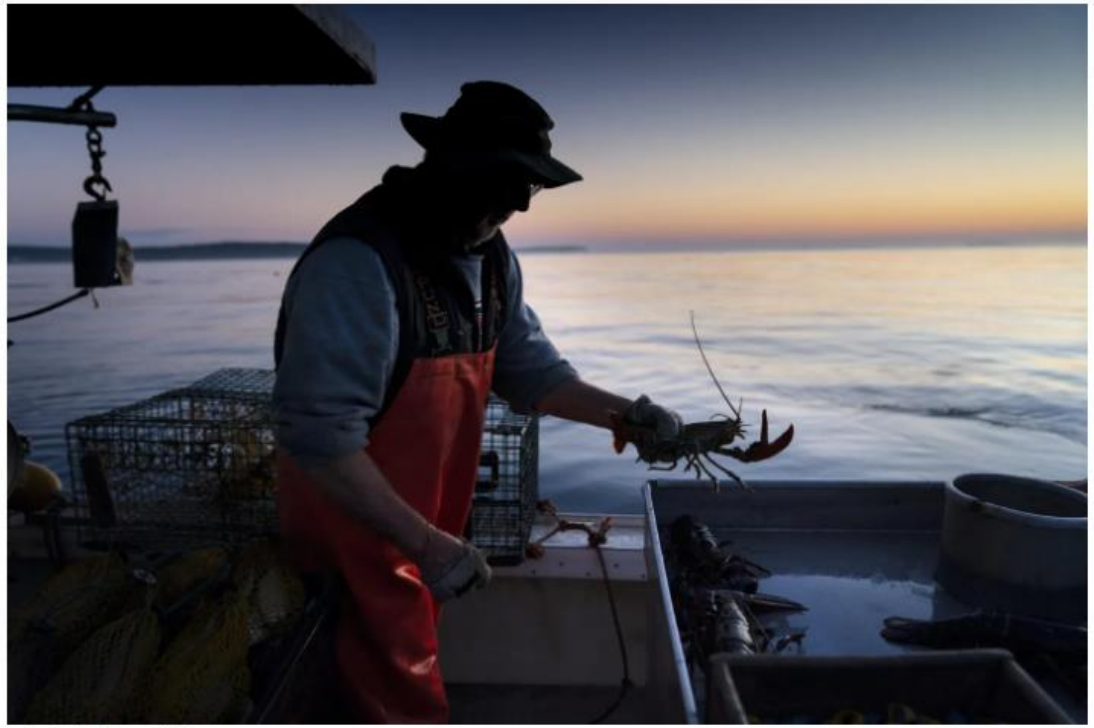
ENVIRONMENT · CLIMATE CHANGE

In just 8 years, Maine's lobster haul has lost nearly 40 million pounds per year: 'There's no question climate change is affecting it'

BY PATRICK WHITTLE AND THE ASSOCIATED PRESS
March 1, 2024 at 12:50 PM CST



Climate change in daily news

REUTERS® World Business Markets Sustainability Legal Breakingviews Technology Investigations More

Climate & Energy | Climate Change

Ocean temperature hit record high in February 2024, EU scientists say

By **Gloria Dickie**

March 7, 2024 3:01 AM CST · Updated 7 min ago

WORLD METEOROLOGICAL ORGANIZATION
Weather Climate Water

Menu Sea

Home / News Portal / Media Releases / WMO confirms that 2023 smashes global temperature

WMO confirms that 2023 smashes global temperature record

PRESS RELEASE

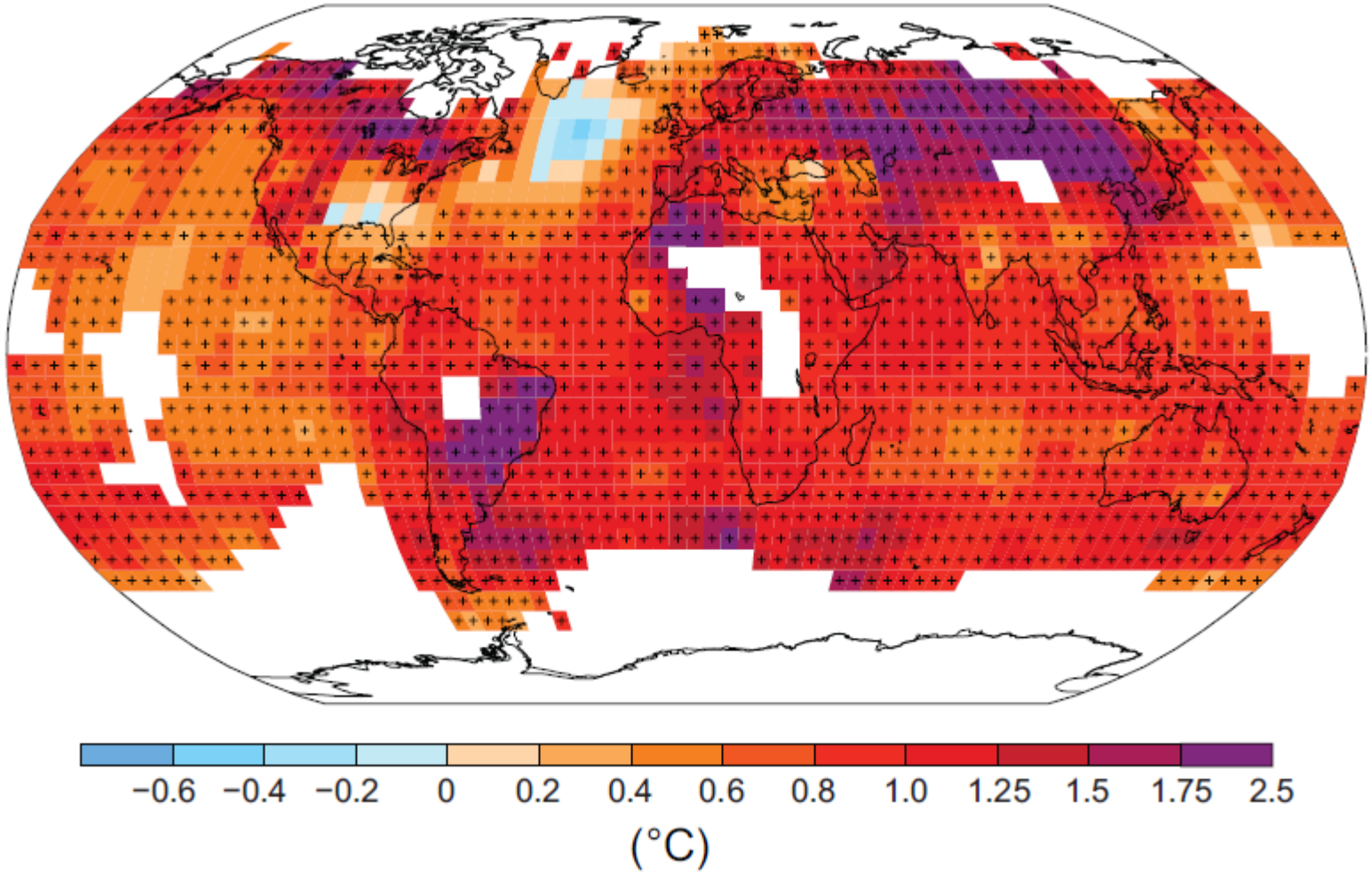
12 January 2024

The World Meteorological Organization (WMO) has officially confirmed that 2023 is the warmest year on record, by a huge margin.

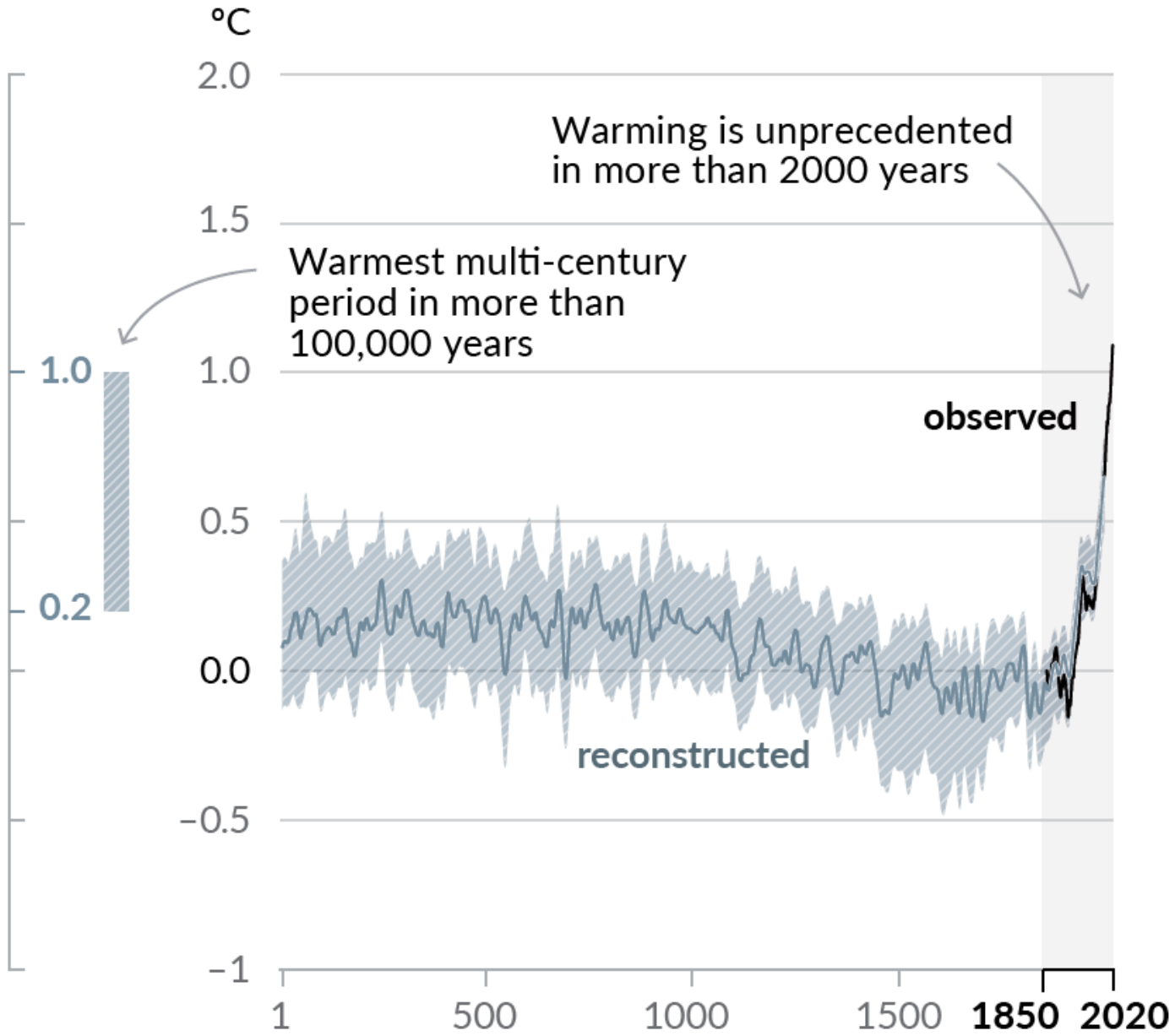
Key messages

Evidences of global warming:

Observed change in surface temperature 1901-2012



(a) Change in global surface temperature (decadal average) as reconstructed (1–2000) and **observed** (1850–2020)



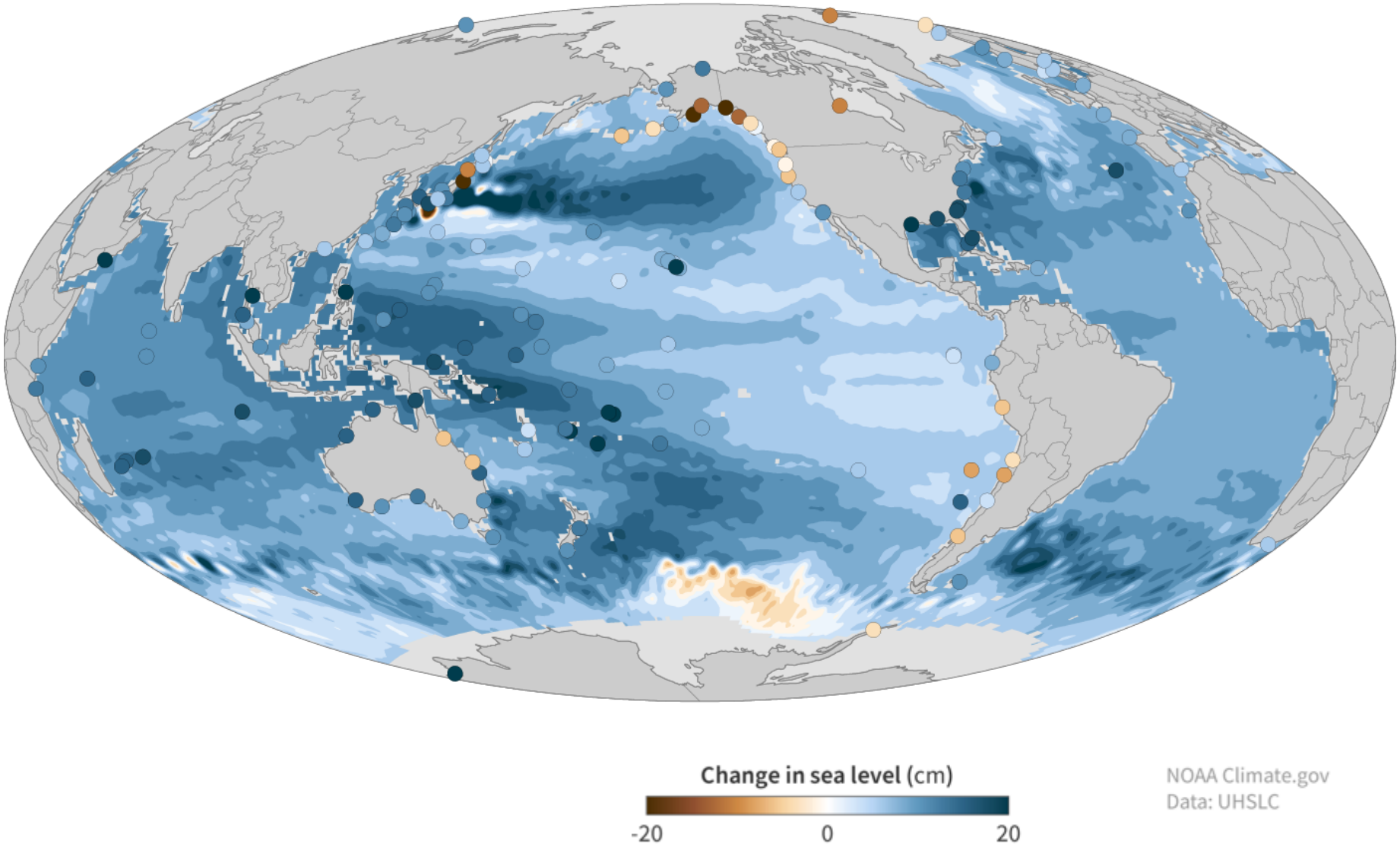
Michael Mann, professor of atmospheric science at the Pennsylvania State University, and author of 'The New Climate War' (Sydney Herdle)

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.

Observed change in sea level 1993-2022



Evidences of Global Warming:
Hydrological Cycle Disrupted

Nature
China drought highlights future clima...

Phys.org
China drought leaves m...

The Guardian
China sends emergency food to drought ...

Reuters
Environment watch

Home - BBC News - BBC
Severe drought hits south-west ...

CCTV
Drought continues to ravage southwes...

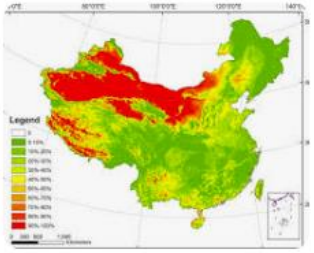
China.org
Severe drought in SW China makes no ...

China Briefing
Northern China suffers through worst ...

Council on Foreign Relations
Water Woes and Worries in China ...

Phys.org
drought may have serious global im...

The New York Times
China Drought Prompts U.N. to Issue ...



ResearchGate
drought frequency in China fro...

Inside Climate News
Drought Turns Southern China...

Wikipedia
2010 China drought and dust storm...

The Guardian
China crisis over Yangtze river drought ...

Facts and Details
DROUGHTS IN CHINA | Facts and ...

East Asia Forum
China and climate change in the post ...

Phys.org
Central China drought worst in over 50 ...

China.org
Drought ravages southwest, north Chin...

Shaktichakra, the wheel of energies - W...
drought of south-west China in pictu...

NBC News
China drills wells, se...

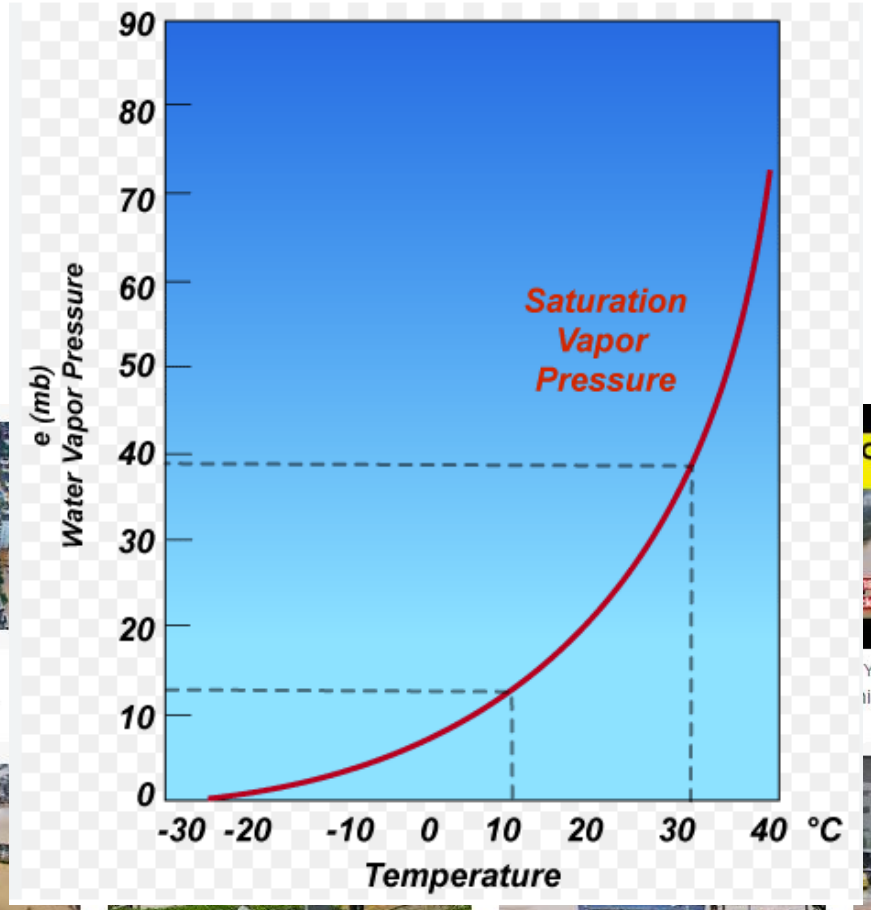
Hydrological Cycle Disrupted

Flooding in China 2024 Summer

CNN
Southern China: Massive floods th...

The Washington Post
Heavy rains batter Chinese provin...

CNN
deadly rains lash southern China ...



YouTube
ina Floods 2024 | Tens Of T...

Le Monde
rainstorm warning issued in southe...

CNN
Southern China: Massive floods t...

Wikipedia
2024 Guangdong floods - Wikipedia

South China Morning Post
floods and droughts grip parts of Chin...

Washington Post
Guangdong braces for historic floods ...

Al Jazeera
Highest-level rainstorm warning is...

CNN
China's deadly flooding moves no...

YouTube
China Flood 2024: Severe Ra...

Reuters
Floods swamp southern China, spark ...

Sky News
China floods: Four dead as cities ...

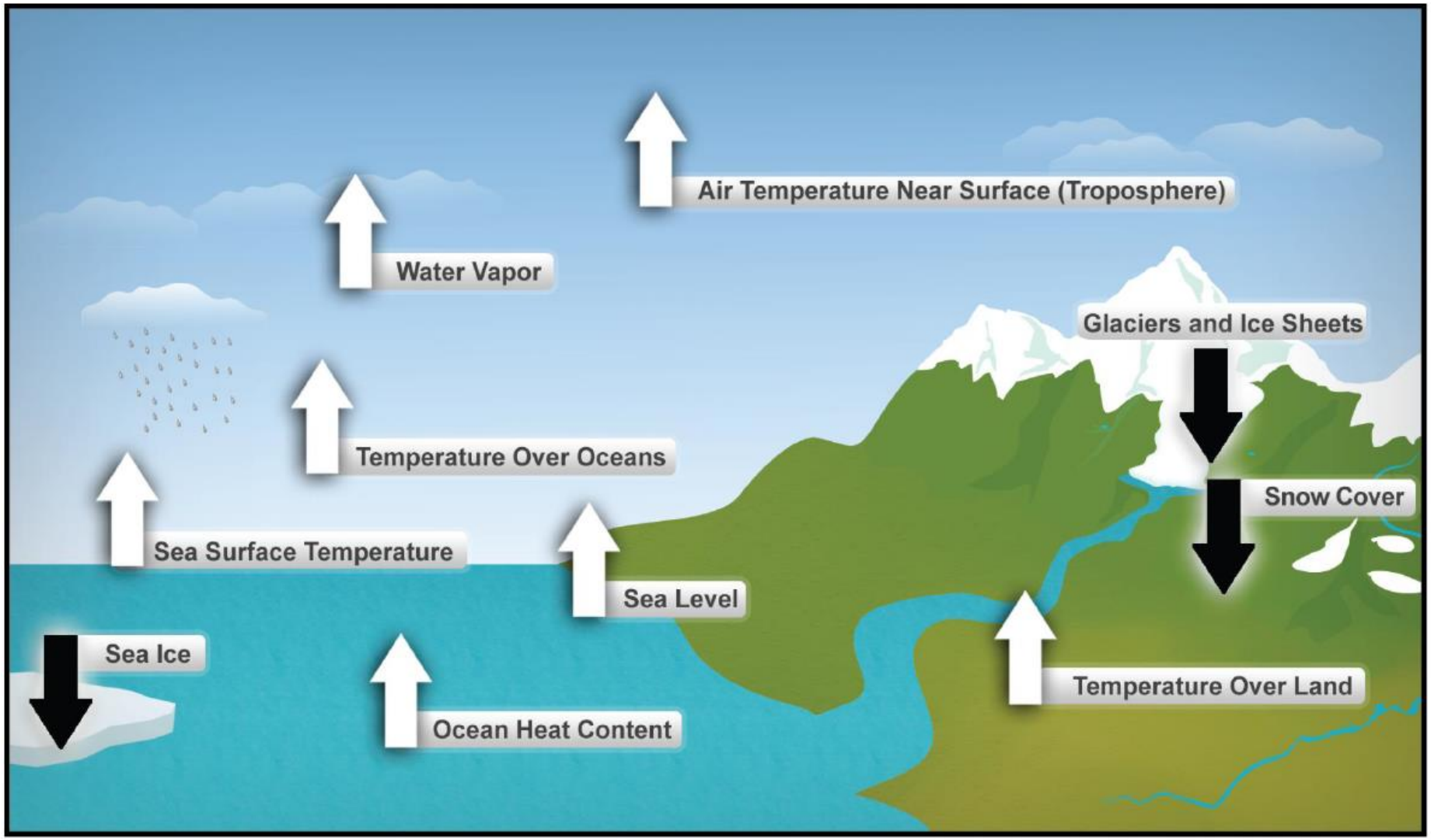
The Washington Post
China wakes to climate change threat a...

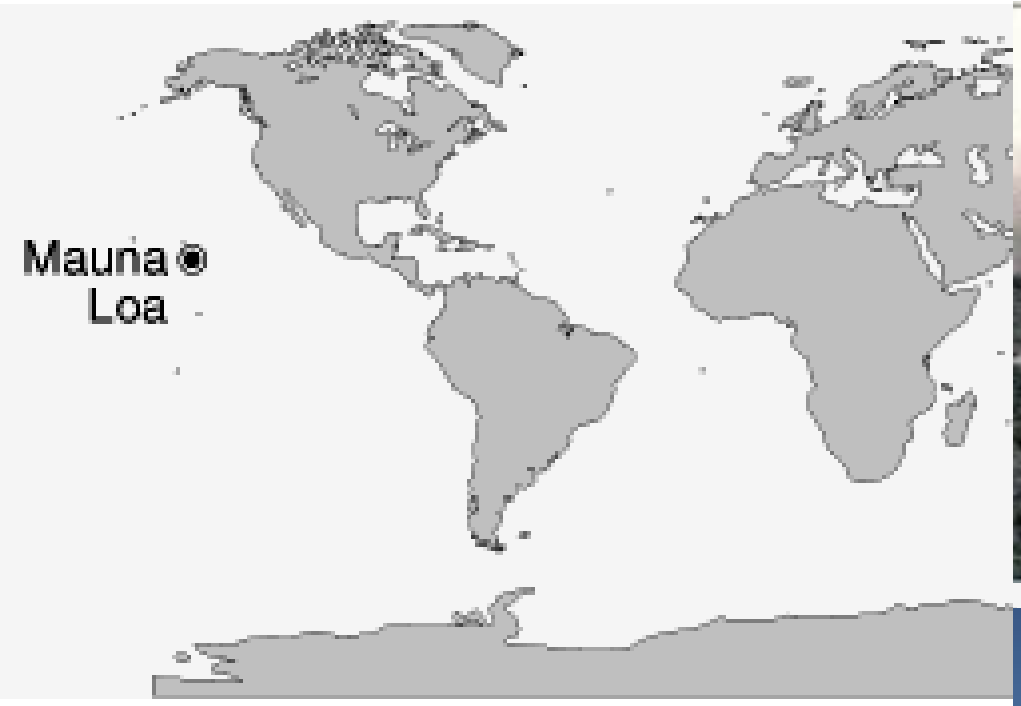
Global Times
China raises flood emergency response ...

News18
China Warns Residents In Southern Par...

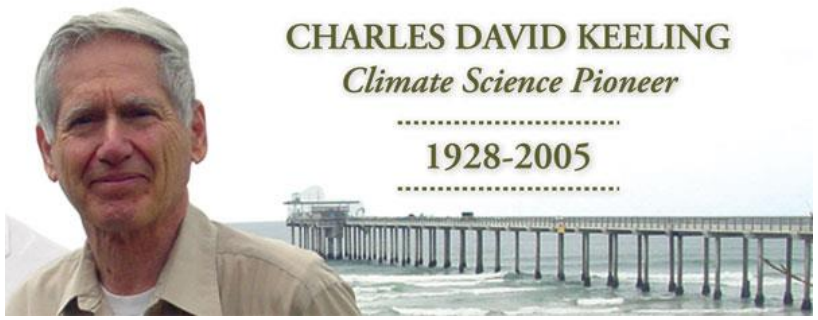
The Watchers News
flood warning issued for Guangdong ...

10 evidences of global warming

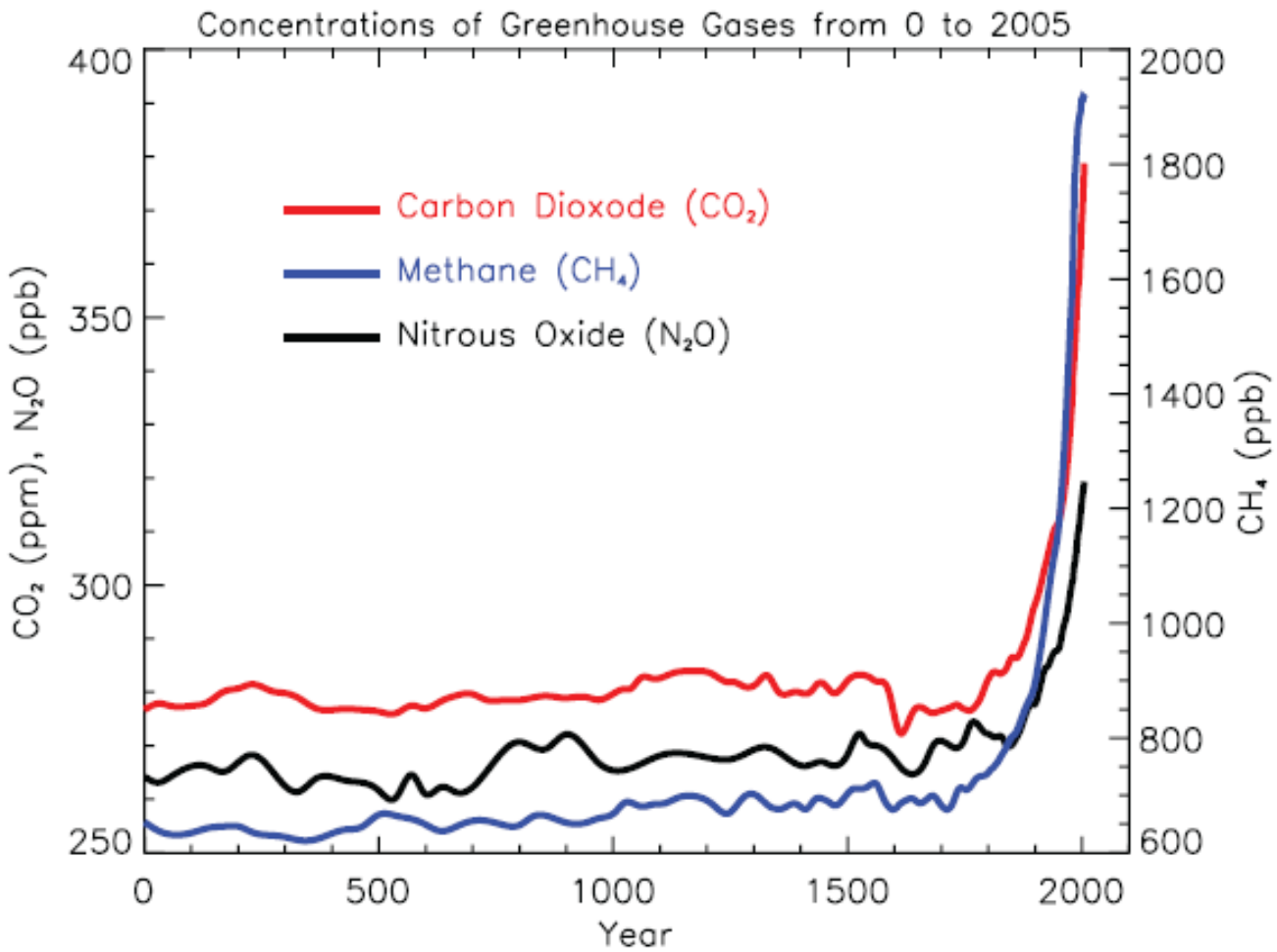


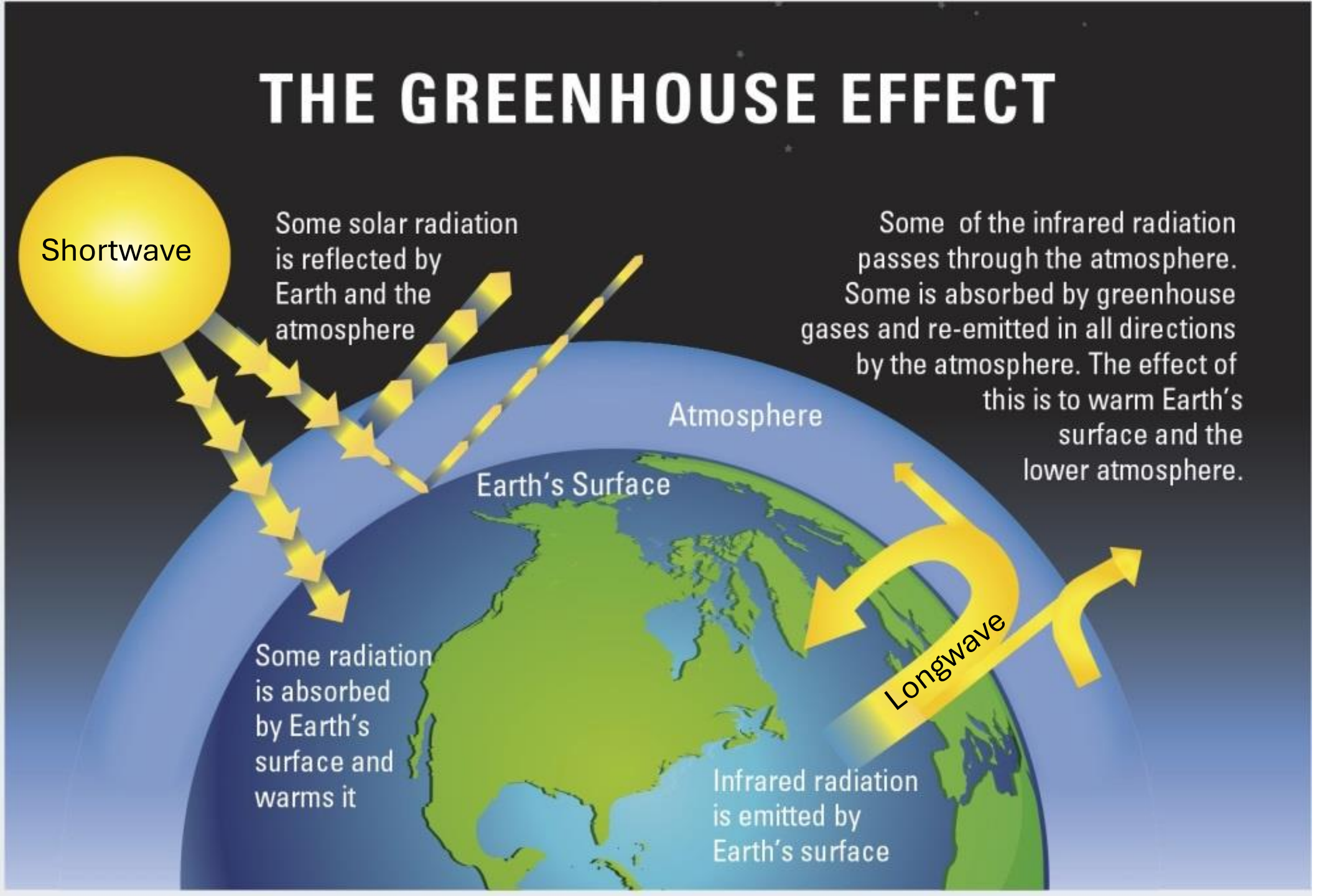

Mauna
Loa


Dedication June 28, 1956


CHARLES DAVID KEELING
Climate Science Pioneer
1928-2005

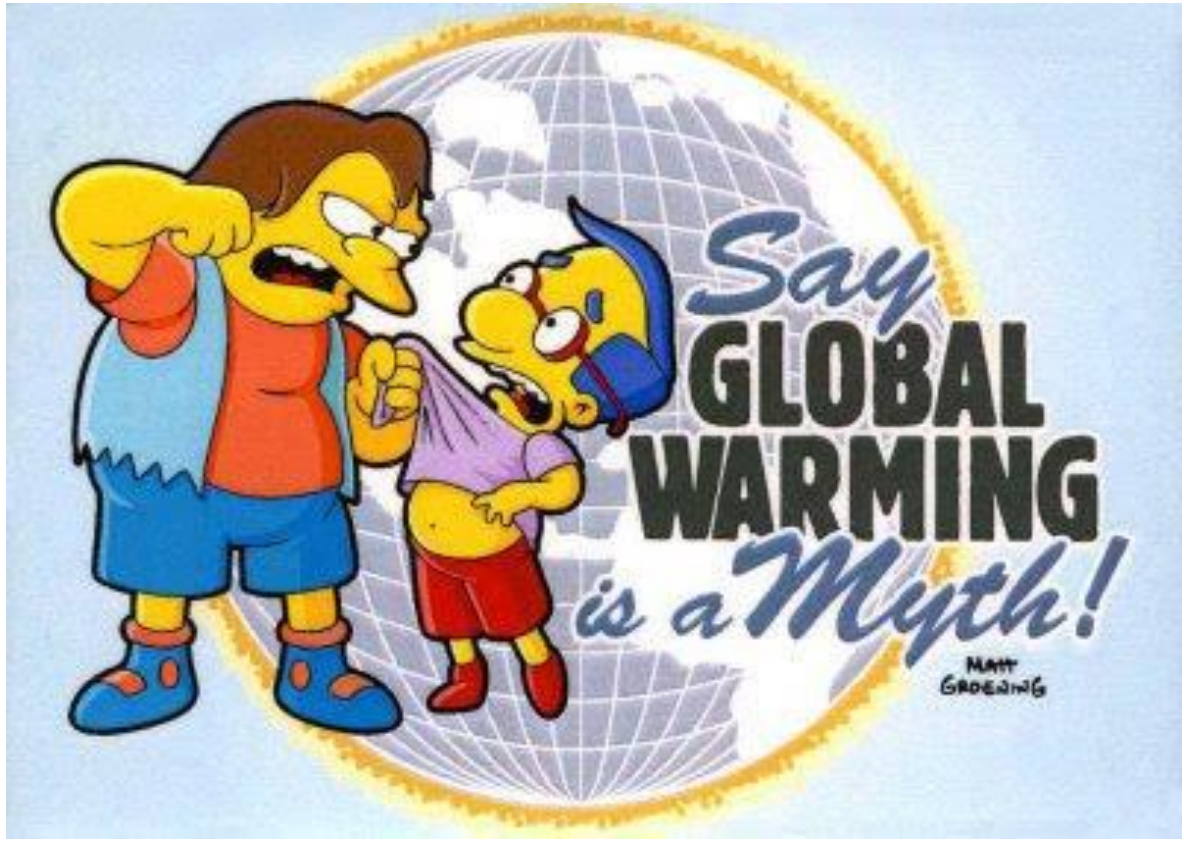
Atmospheric CO_2, CH_4, N_2O growth trend




THE GREENHOUSE EFFECT
Shortwave
Some solar radiation is reflected by Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere. Some is absorbed by greenhouse gases and re-emitted in all directions by the atmosphere. The effect of this is to warm Earth's surface and the lower atmosphere.
Atmosphere
Earth's Surface
Some radiation is absorbed by Earth's surface and warms it
Longwave
Infrared radiation is emitted by Earth's surface

Are climate change and global warming real?

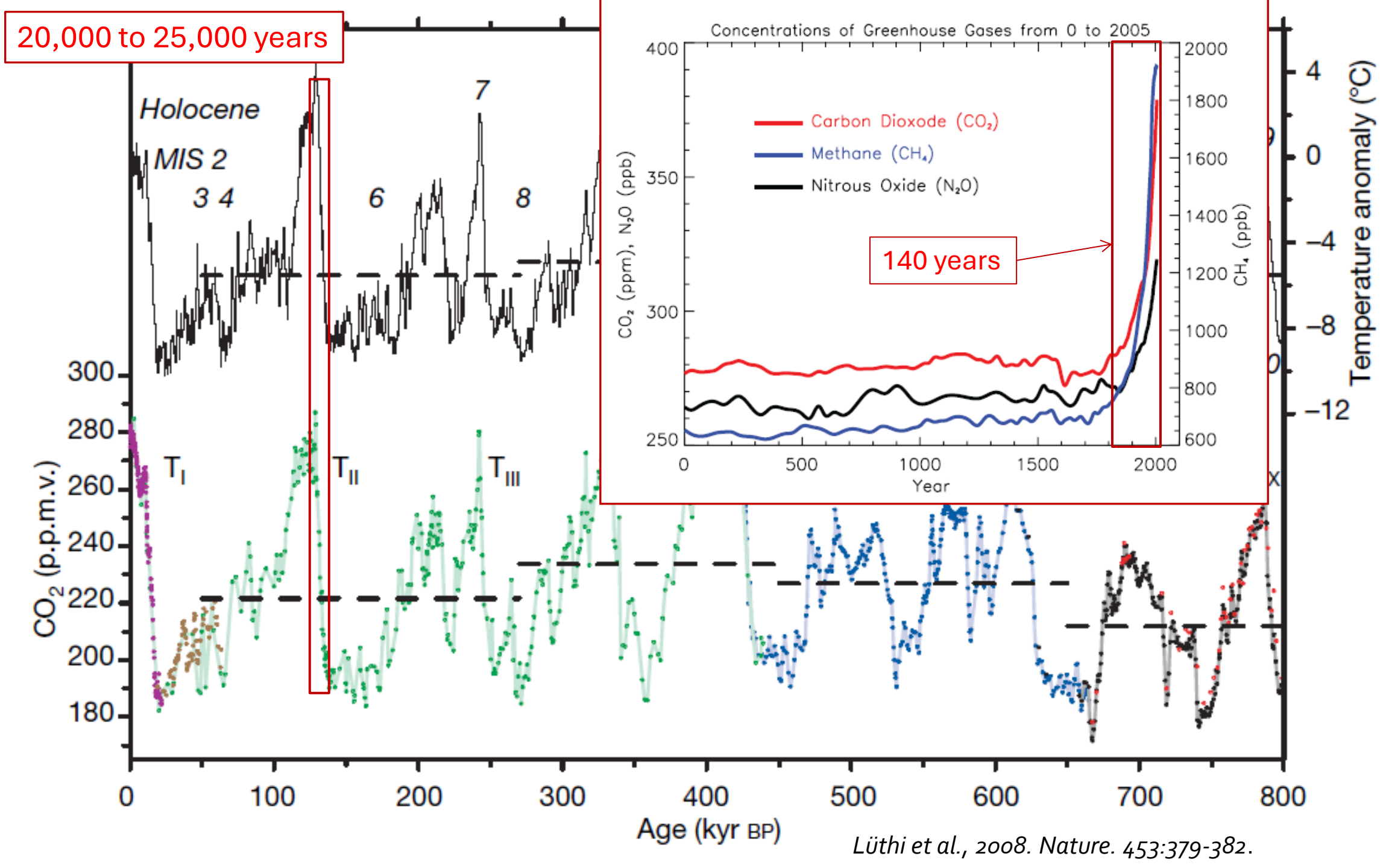
Just a hoax ?
Weather or Climate?
Or too many other crises going on?



Different response of social society to some discoveries of earth science

- Theory of Evolution: 1860s
- Theory of the Ice Ages: 1900s
- Theory of Plate Tectonics: 1960s
- Theory of Ozone Layer Depletion (because of CFC)
- Theory of Global Warming: 2000s

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



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

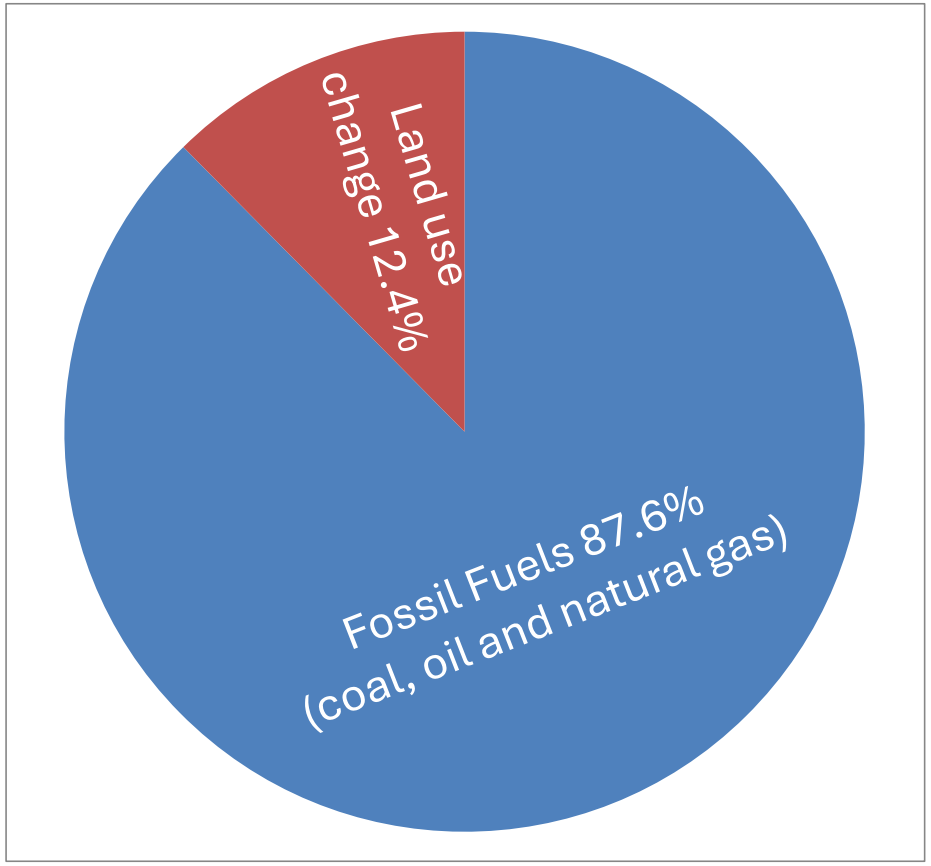
Major Greenhouse Gases

Greenhouse Gas	Current Atmospheric Concentration	Atmospheric Lifetime (year)	Global Warming Potential (全球增温潜势)	Radiative Forcing (W m^{-2}) (辐射强迫)
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

Significance

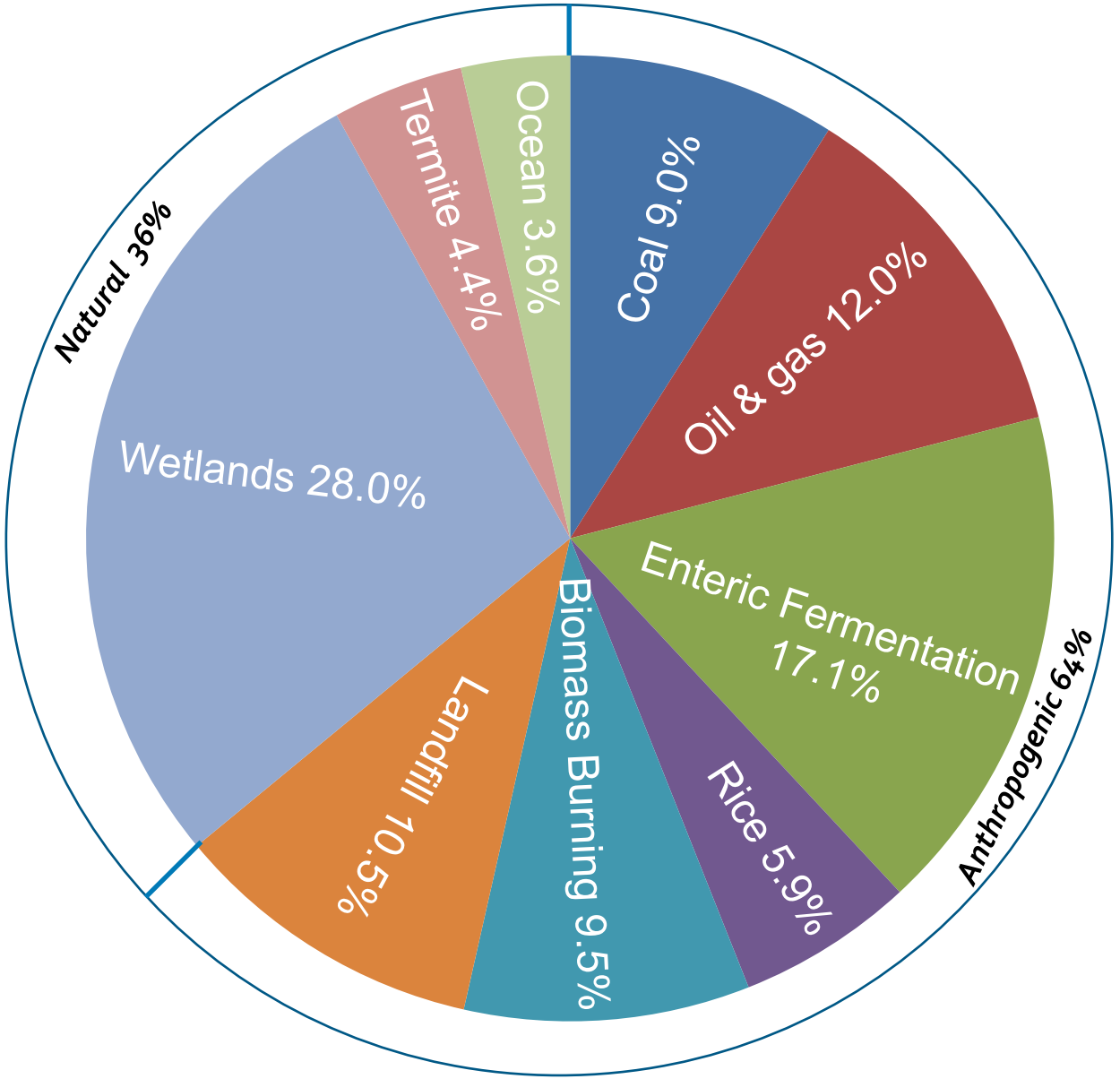
Global CO_2 Sources

100% anthropogenic



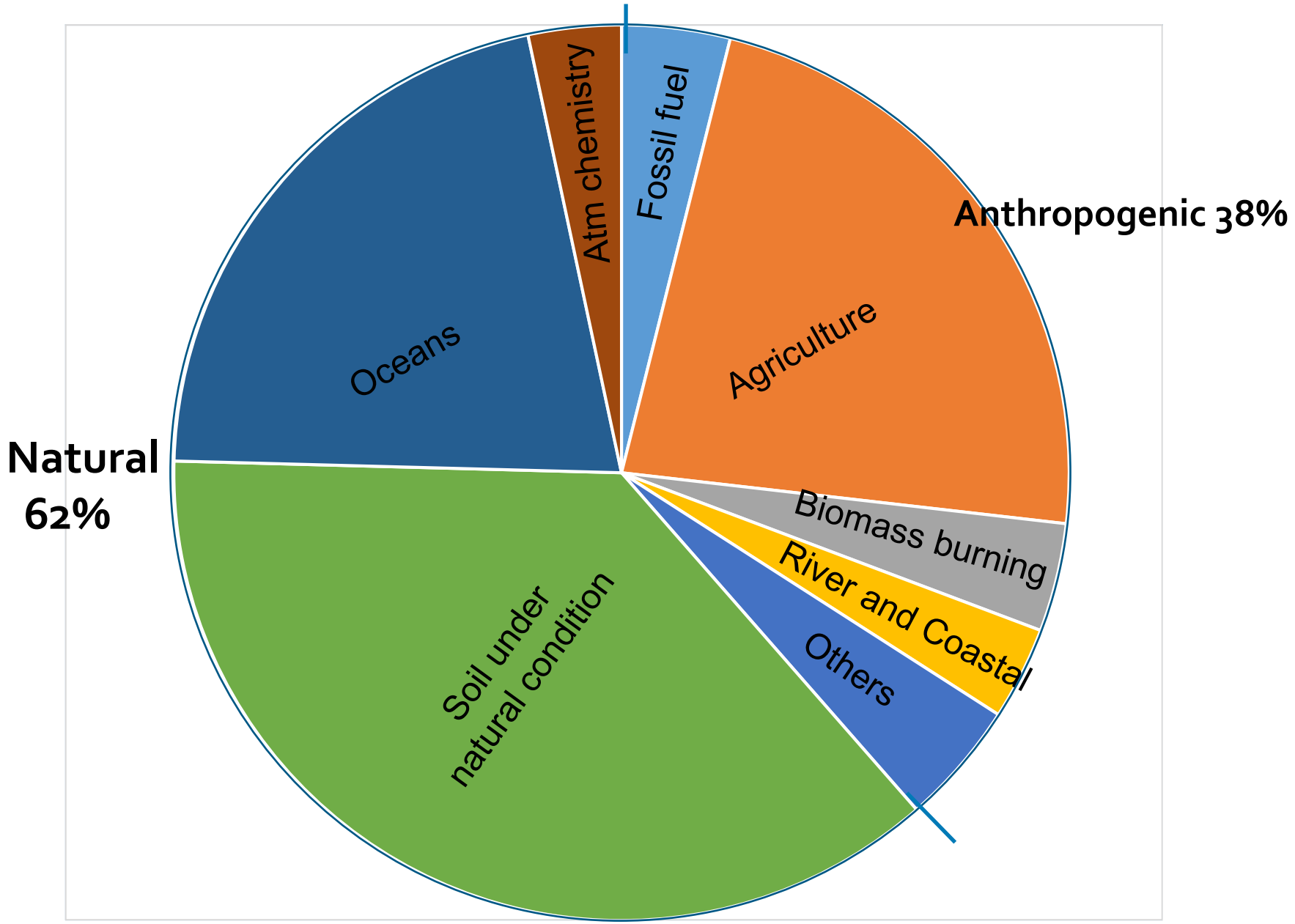
Quere et al., 2014. Earth System Science Data Discussion

Global CH_4 Sources (源)



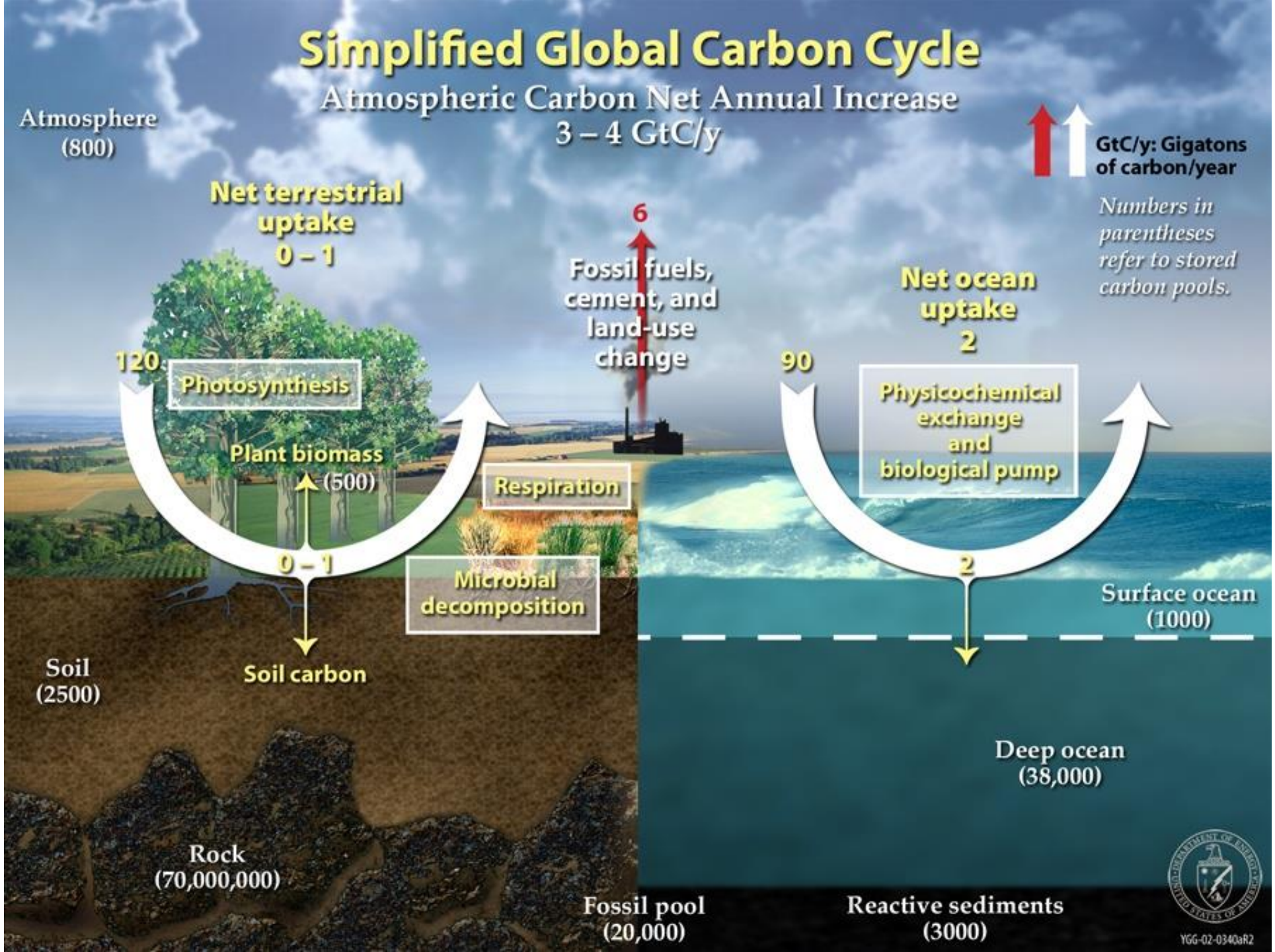
Dlugokencky et al., 2012. Philosophical Transactions of the Royal Society A

Global N_2O Sources （源）



GHG cycle study

- What are the sources, sinks of CO_2, CH_4, N_2O (库和源)?
- 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)?
- What are the factors that regulate these source and sink strength （调控）?
- Research approach (研究方法)
  - Atmospheric background, like Global Atmosphere Watch of WMO
  - Remote sensing, large scale modeling
  - Ecosystem level study
  - Isotope
- Mitigation strategies (应对措施)



GtC=10^9 tonnes C

Atmospheric CO_2, CH_4, N_2O trend (变化趋势)?

GAW (Global Atmosphere Watch Program)

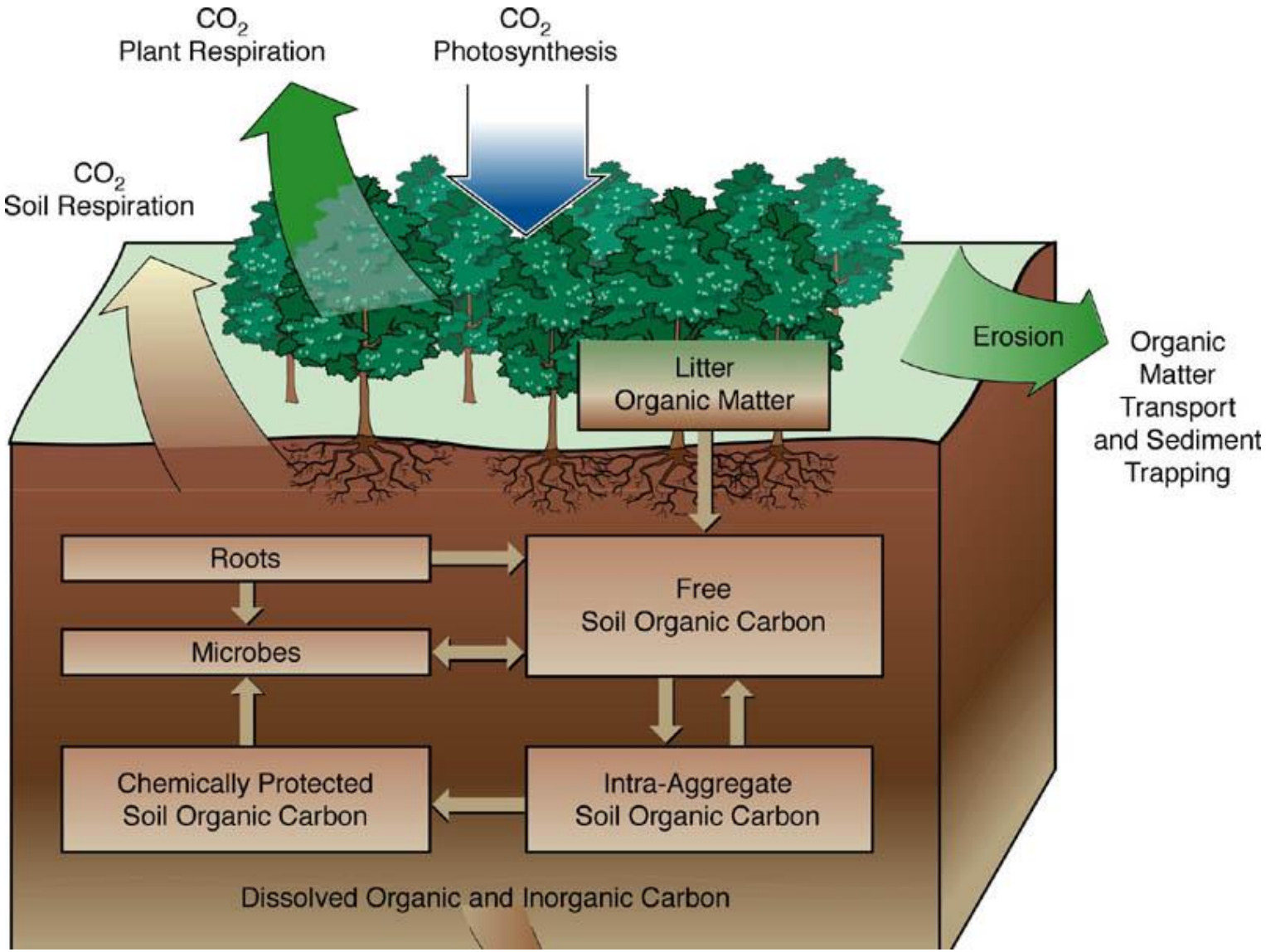
Atmospheric CO_2, CH_4, N_2O trend (变化趋势)?

GAW (Global Atmosphere Watch Program)

Gas Species	Inter-lab comparability
CO_2	± 0.1 ppm (±0.05 ppm in southern Hemisphere)
$\delta^{13}C$-CO_2	± 0.01 per mil
CH_4	± 2 ppb
CO	± 2 ppb
N_2O	± 0.1 ppb
H_2	± 2 ppb

14th WMO/IAEA meeting of experts on carbon dioxide, other greenhouse gases and related tracer measurement techniques

What kind of impact on climate and ecosystem, esp for the case of CO2 (影响)?



Manipulation of precipitation (rainfall event size and frequency) experiment

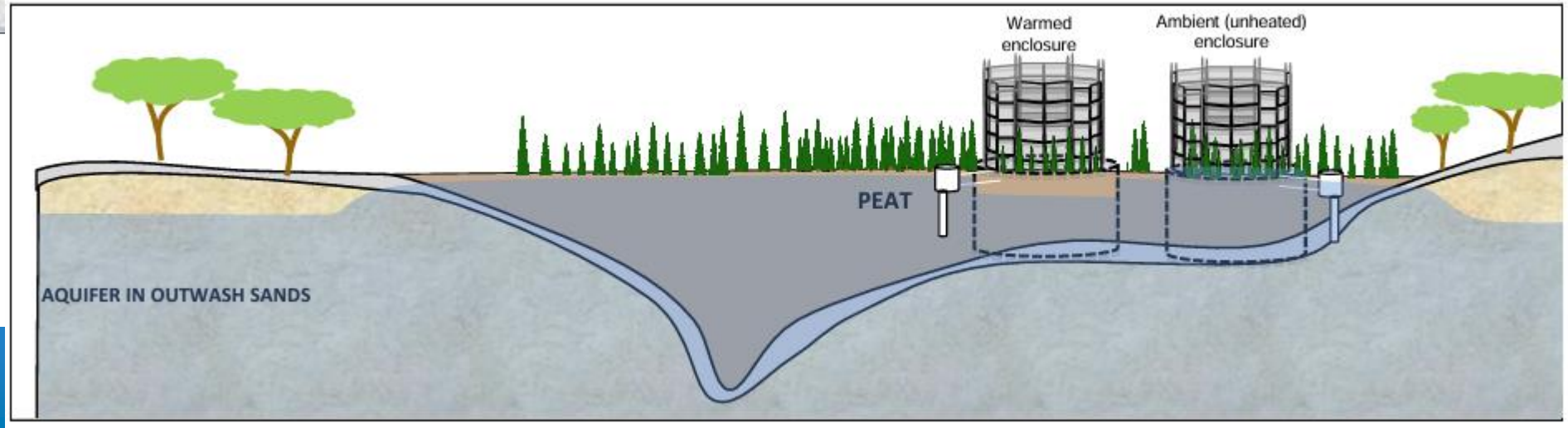
At Sevilleta LTER, New Mexico

Soil Warming Experiment: Harvard Forest LTER Station

FACE Program,

FACE and Warming Program,

SPRUCE exp (Warmed enclosure vs. Ambient enclosure), Northern Minnesota

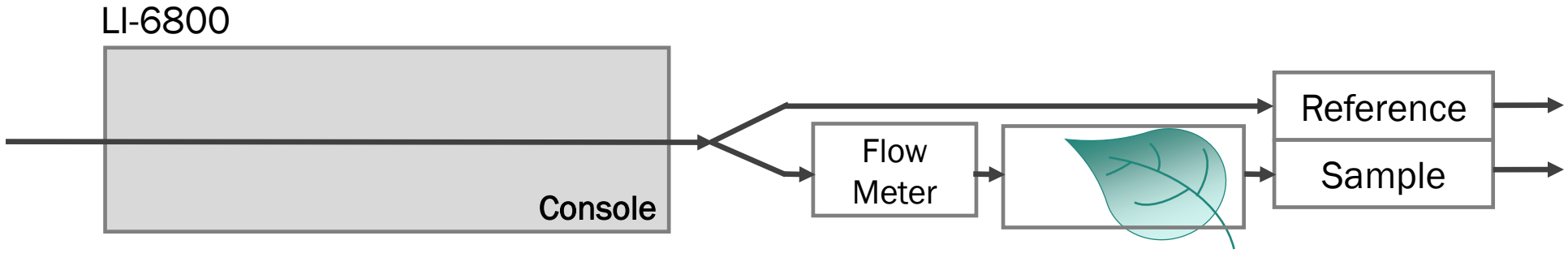


ABOUT THE LTER NETWORK

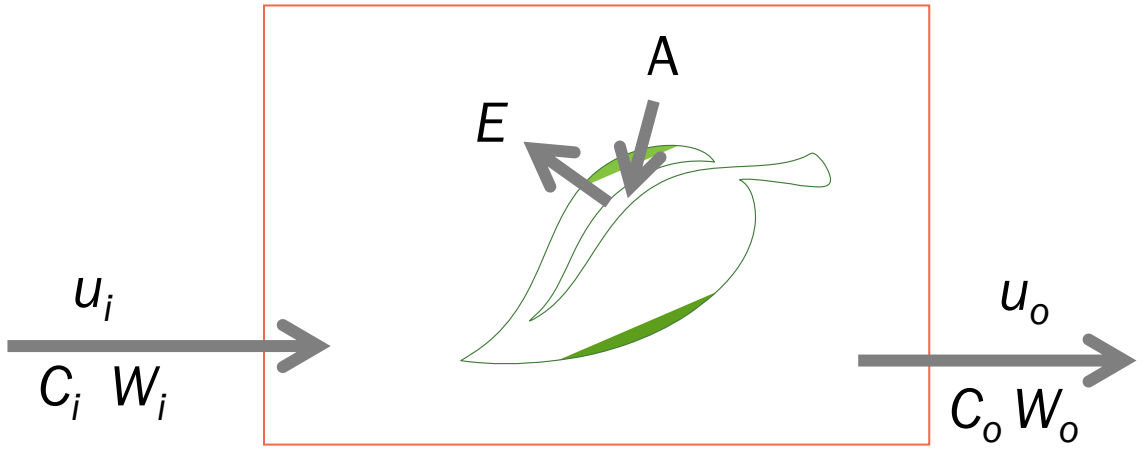
Undergraduates lead school tours of the REEF, ***Credit:*** *SBC-LTER*

K-12 students collect plant growth data.HAS_LTER

Flux measurement at leaf level:



Flux measurement at leaf level:



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

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

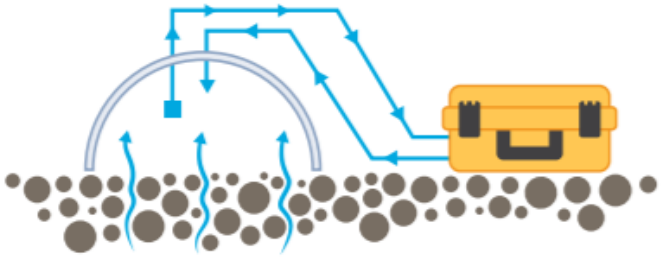
S: leaf area (cm^2)
E: transpiration (mmol $m^{-2}s^{-1}$)
u: flow rate (μmol s^{-1})
W: concentration of water vapor (mmol mol^{-1})
A: carbon assimilation (μmol $m^{-2}s^{-1}$)
C: concentration of CO_2 (μmol mol^{-1})

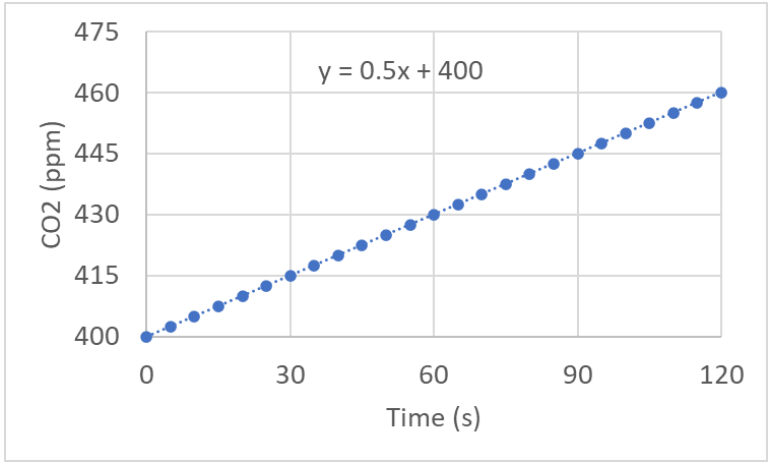
Stomata conductance, g_s,

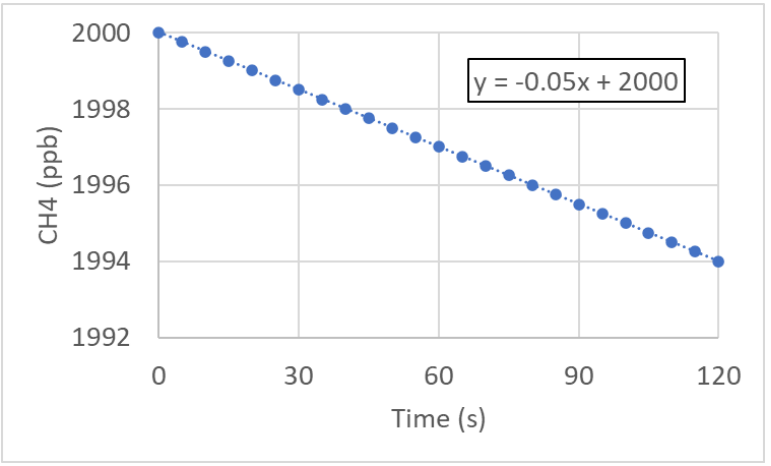
V_{cmax}, J_{max},

F_v/F_m,

Flux measurement across soil surface







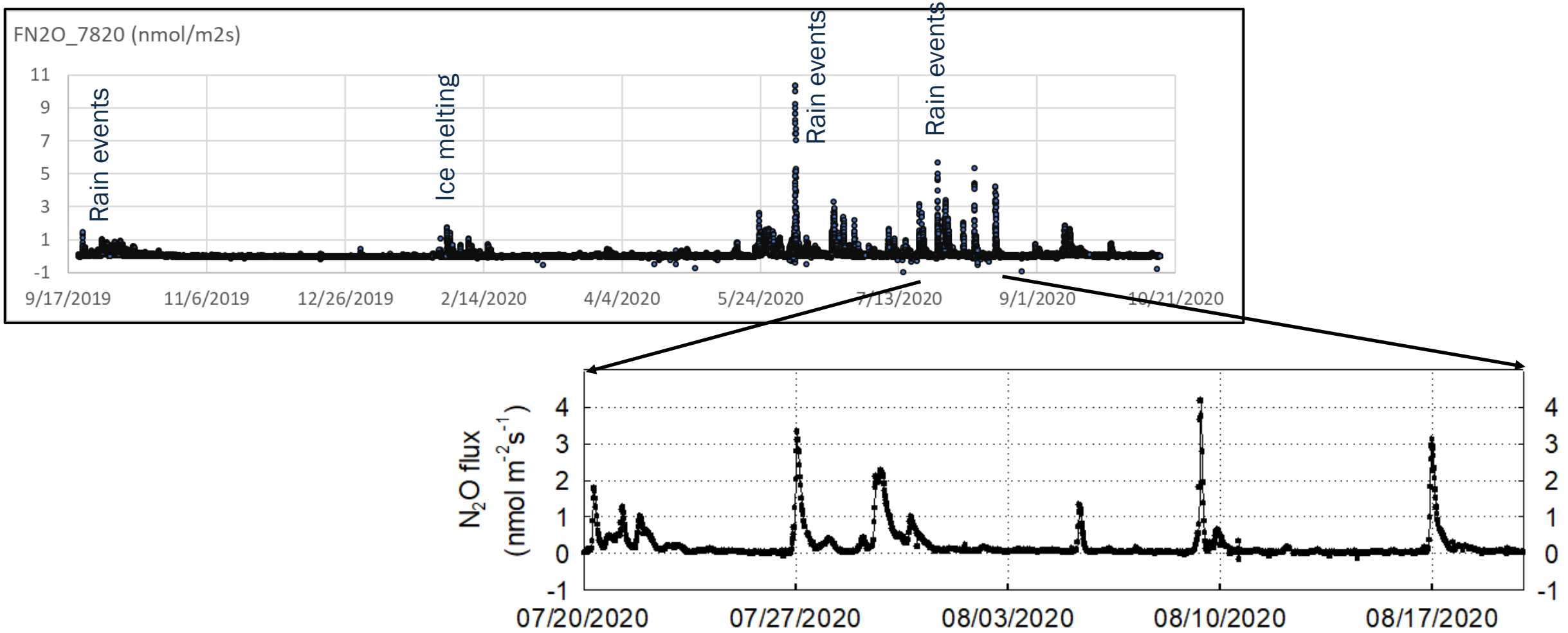
$$F_{CO2} = \frac{VP_o(1 - W_o)}{RS(T_o + 273.15)} \frac{dC}{dt}$$

V:	Chamber volume	m^3
P_o:	Pressure	Pa
R:	Gas constant	Pa m^3 $k^{-1}mol^{-1}$
S:	Soil area	m^2
T_o:	Initial temperature	^oC
$\frac{dC}{dt}$	Slope	µmol $mol^{-1}s^{-1}$
W_o	Initial H_2O	mol mol^{-1}
F_{CO2}:	Flux	µmol $m^{-2}s^{-1}$

Flux measurement at leaf level: Automated and Long-term system (LI-8250)

Advantage of automated and continuous measurement:

- Can have fine temporal variation

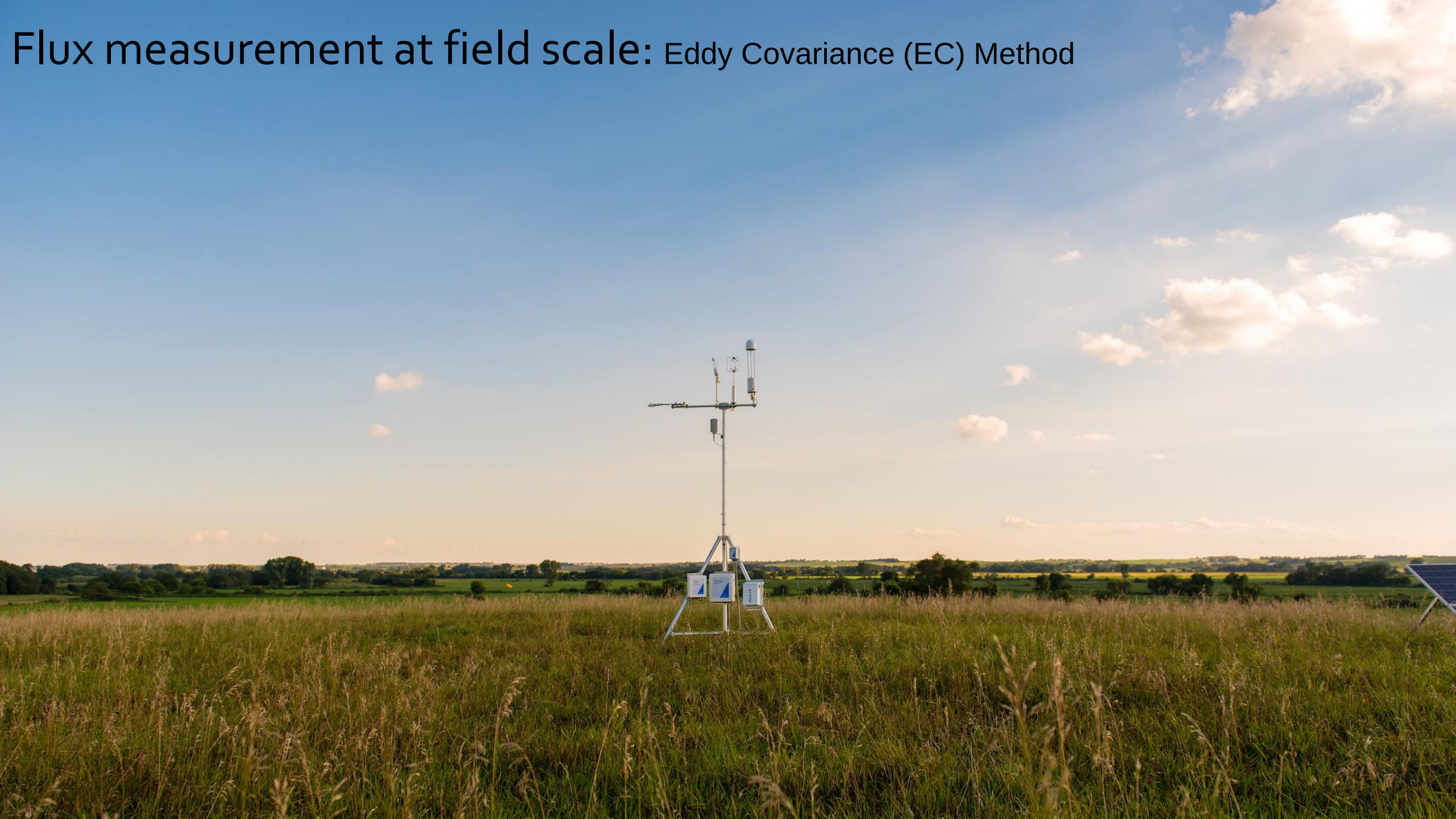


Flux measurement across soil surface:

Advantages of chamber method

1. Simple theory
2. Can measure very small flux (depend on volume to area ratio, precision of the gas analyzer)
3. Relatively easier to process the data
4. Can be used over small plots
5. Can be used over a wide range of field topography

Flux measurement at field scale: Eddy Covariance (EC) Method

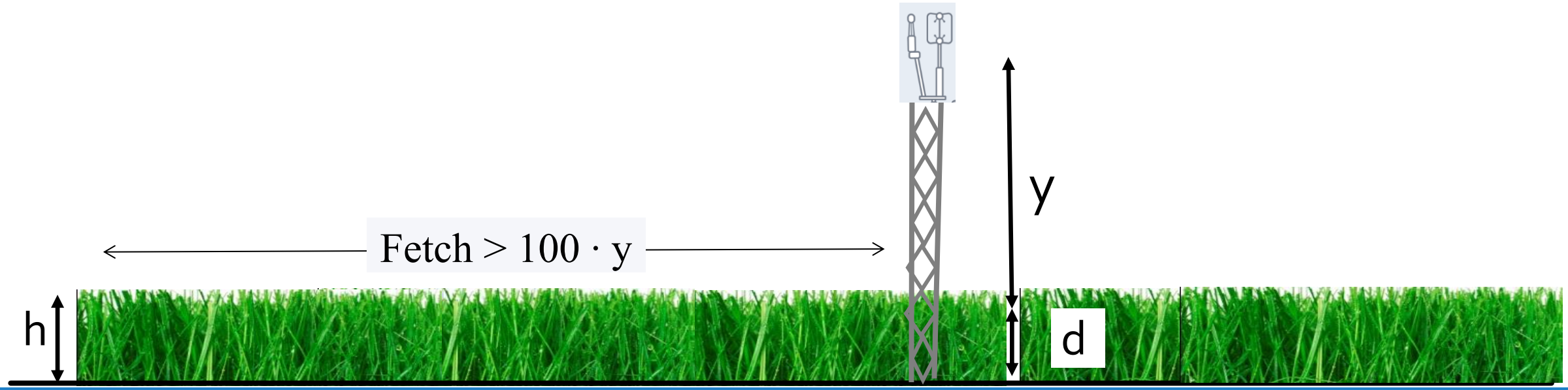


Flux measurement at field scale: Eddy Covariance (EC) Method

$$F = \overline{w'c'} = \frac{1}{18000}\sum_{i=1}^{18000}(w-\bar{w})(c-\bar{c})$$

Can measure flux over large area

Instrument height (m)	Radius (m)	Footprint area (ha)
2	200	12.6
10	1000	314.2
20	2000	1256.8
50	5000	7854.0



Flux measurement at field scale: Eddy Covariance (EC) Method

Advantages over other methods

- Direct measurement of the flux density
- *in situ*
- No disturbance to your system
- Continuous
- Represents a large area in the upwind direction

Research areas (机理)

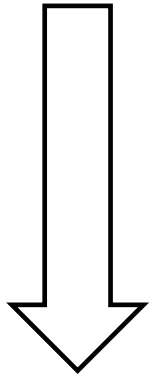
- NEE, ET = f(PAR, diffuse radiation, temperature, soil moisture, rain pulse, and other environmental variables)

- NEE, ET = f(elevation gradient, land use, plant functional type, length of growing season, drought, disturbance of fire, logging and thinning, forest age, insect infestation)

- CH_4 and N_2O ecosystem budget, fish farms, lake, river etc

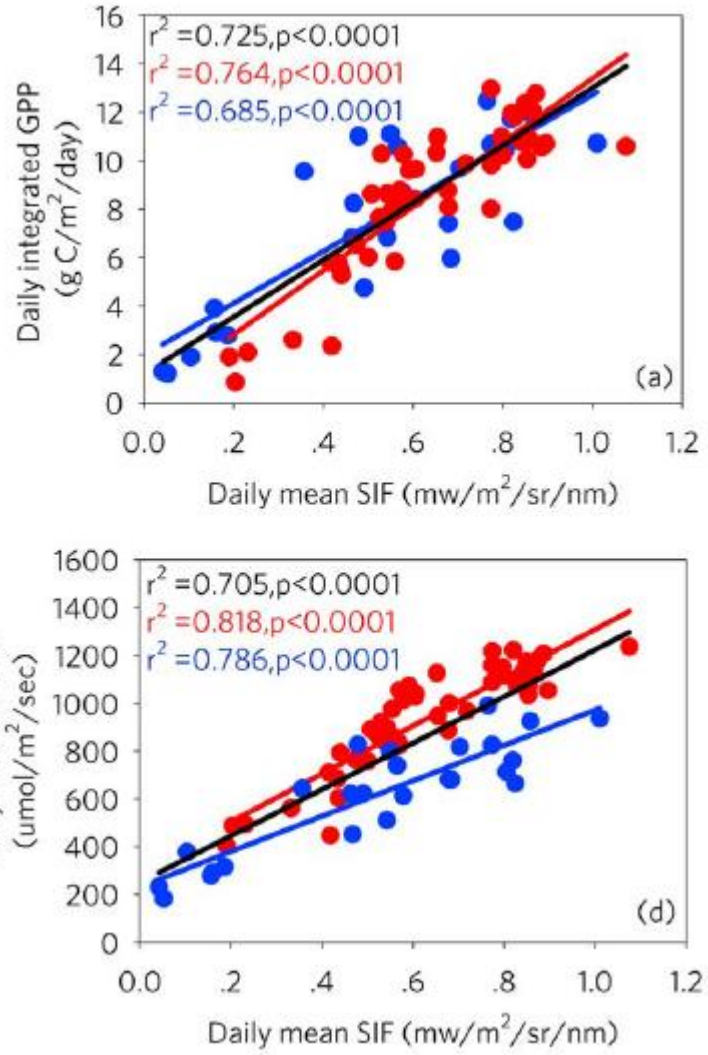
- Crop field carbon sequestration potential, deserts

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

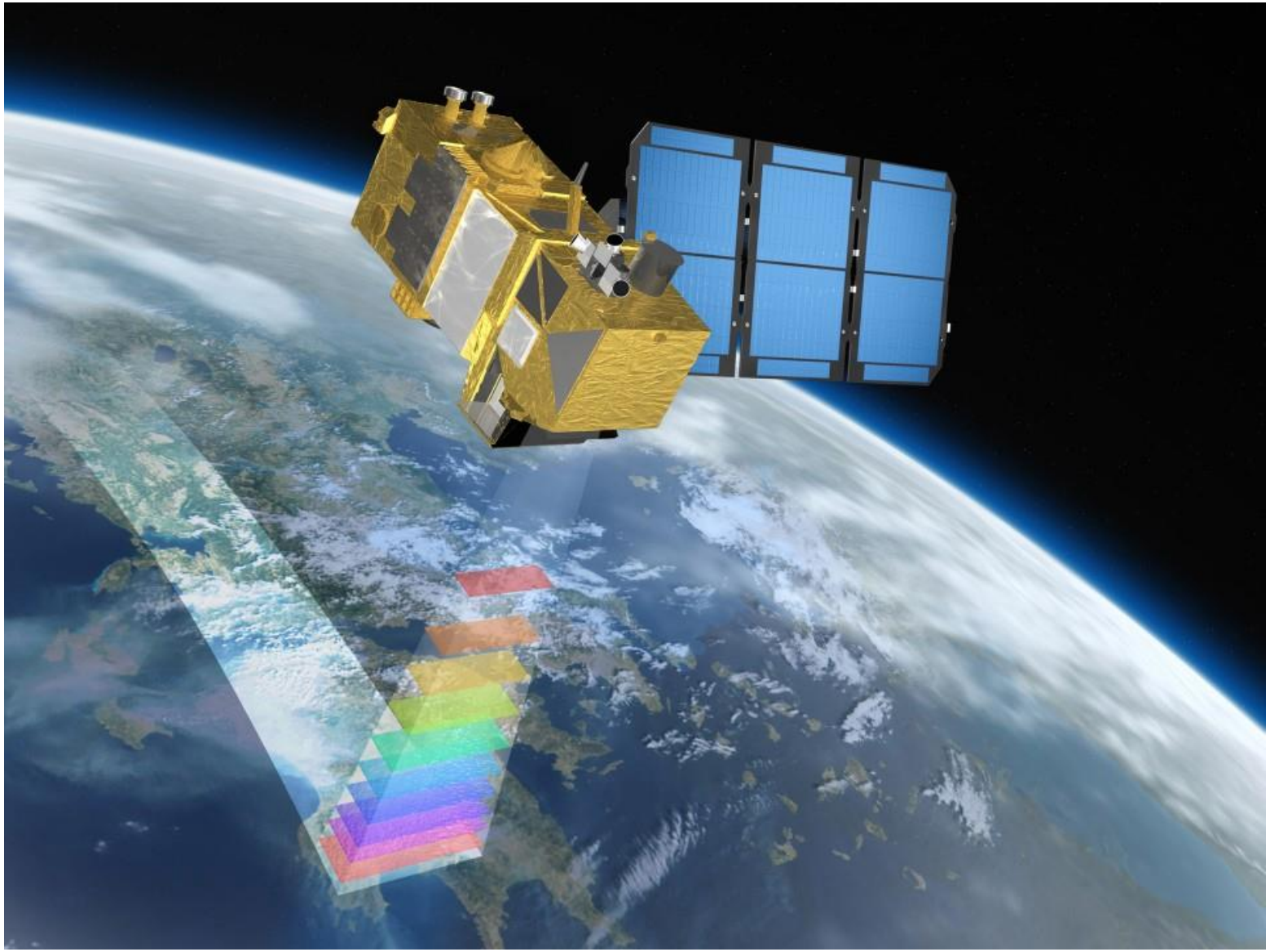


model validation, ground truth, and remote sensing

Remote sensing



Yang et al., GRL 2015



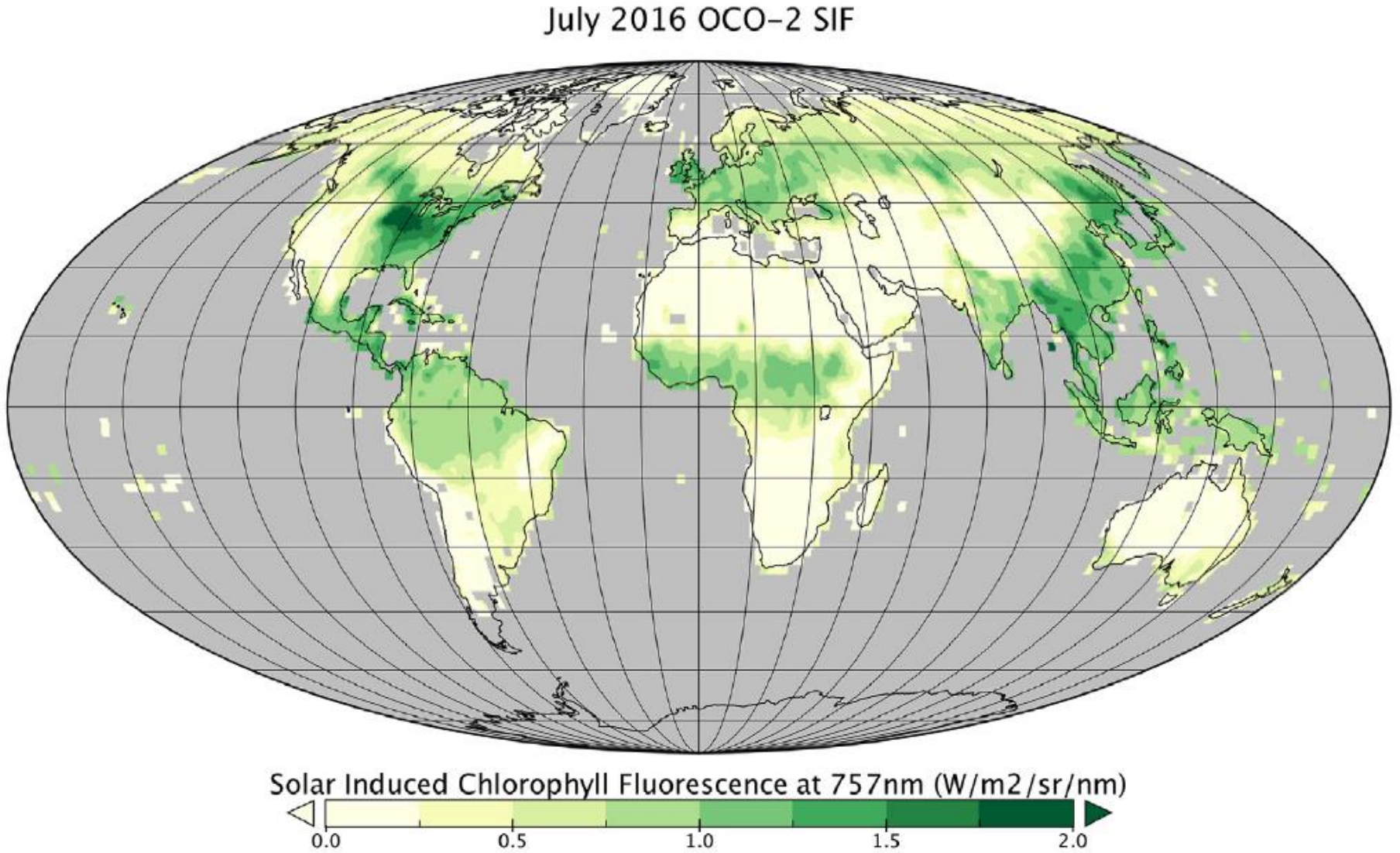
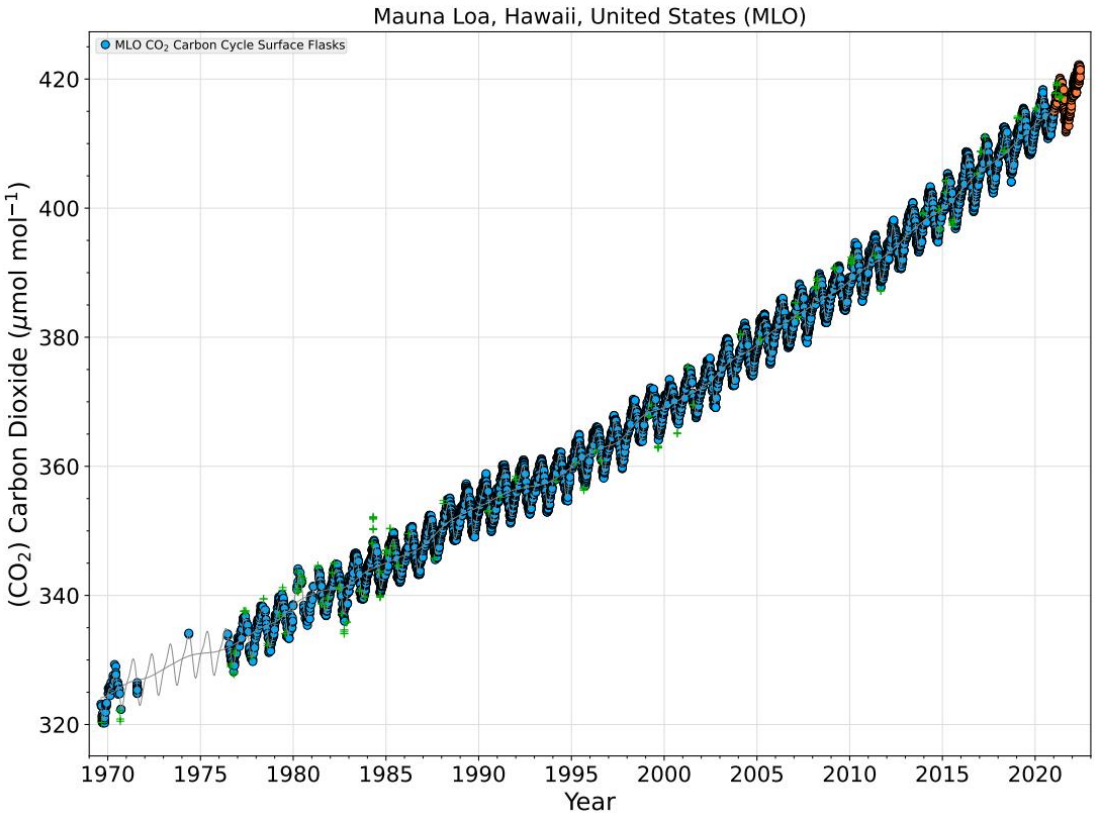
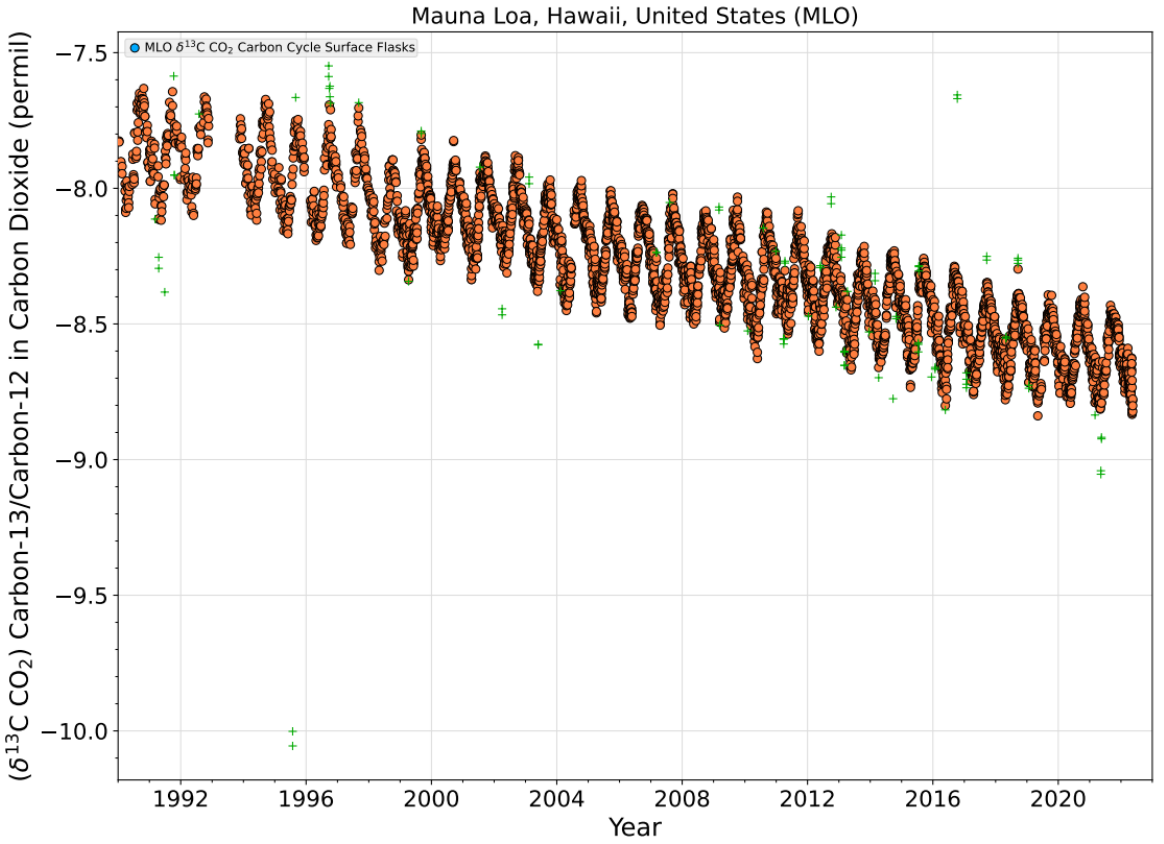


Fig. 4 SIF monthly average from July 2016 using data from the Orbiting Carbon Observatory-2. The corn belt in the United States can be clearly observed as a dominant feature, as was initially reported by Guanter et al. (2007).

Need to explain this plot



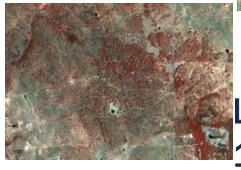


The more and more negative in $\delta^{13}C$ proves that the atmospheric CO_2 concentration increase is due to the release of CO_2 from burning of fossil fuel.

Spatial scale for carbon cycle study

Globe: 10,000 km

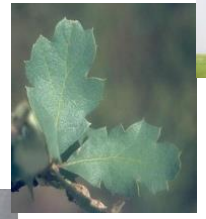
Biome/ Continent: 1000 km



Landscape/Ecosystem/Community
1 - 100 km

Canopy: 100 - 1000 m; km

Soil and Plants, 1 - 10 m; m



Leaf/Needles: 0.01 - 0.1 m; mm, cm

Stomata: 10^{-5} m; µm

Bacteria/Chloroplast/Cell/Organelle: 10^{-6} m; µm

(Courtesy of Dr. Baldocchi)

LI-COR

Mitigation strategies (government):

1. Plant more trees?
   - Water and nutrient limitation
   - Land limitation
2. Carbon capture and storage
   - Inject CO_2 underground
3. Cut emission
   - More efficient transportation, Heating/AC
4. EV
   - Depends on how the electricity is generated?
5. Solar power, wind, nuclear energy
   - More efficient than biofuel
6. Cut emission of CO_2, CH_4 and N_2O

Topics covered today

- Evidences: Global warming and climate change
- Ecosystem response to climate change and global warming
  - FACE
  - Warming
  - Manipulate precipitation
- Carbon cycle study
  - **GHG and energy flux measurement(leaf level, soil surface, canopy)**
  - **Remote sensing, e.g. SIF**
  - **Isotope**
- Mitigation strategies

谢 谢 大 家

Q&A