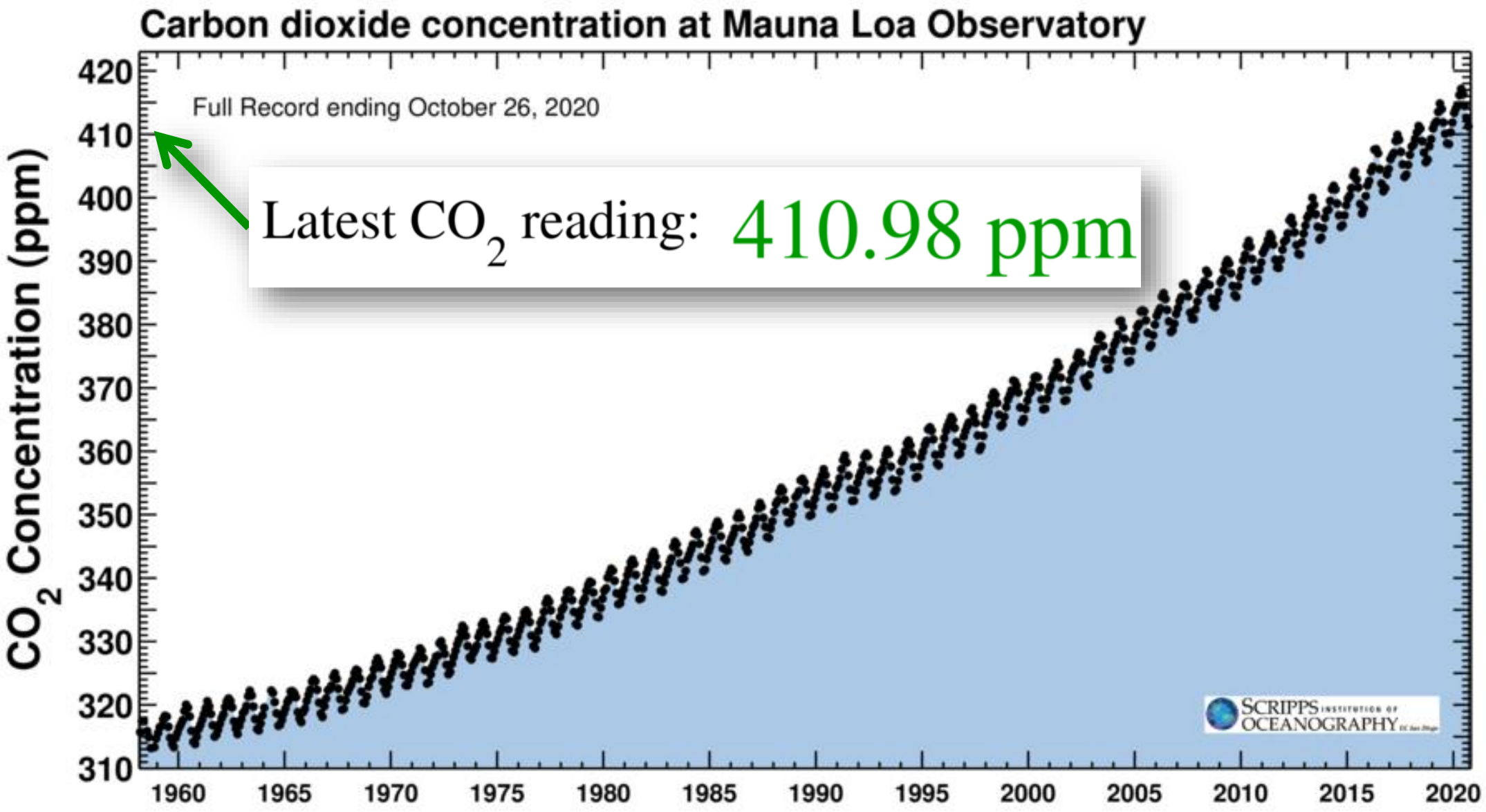
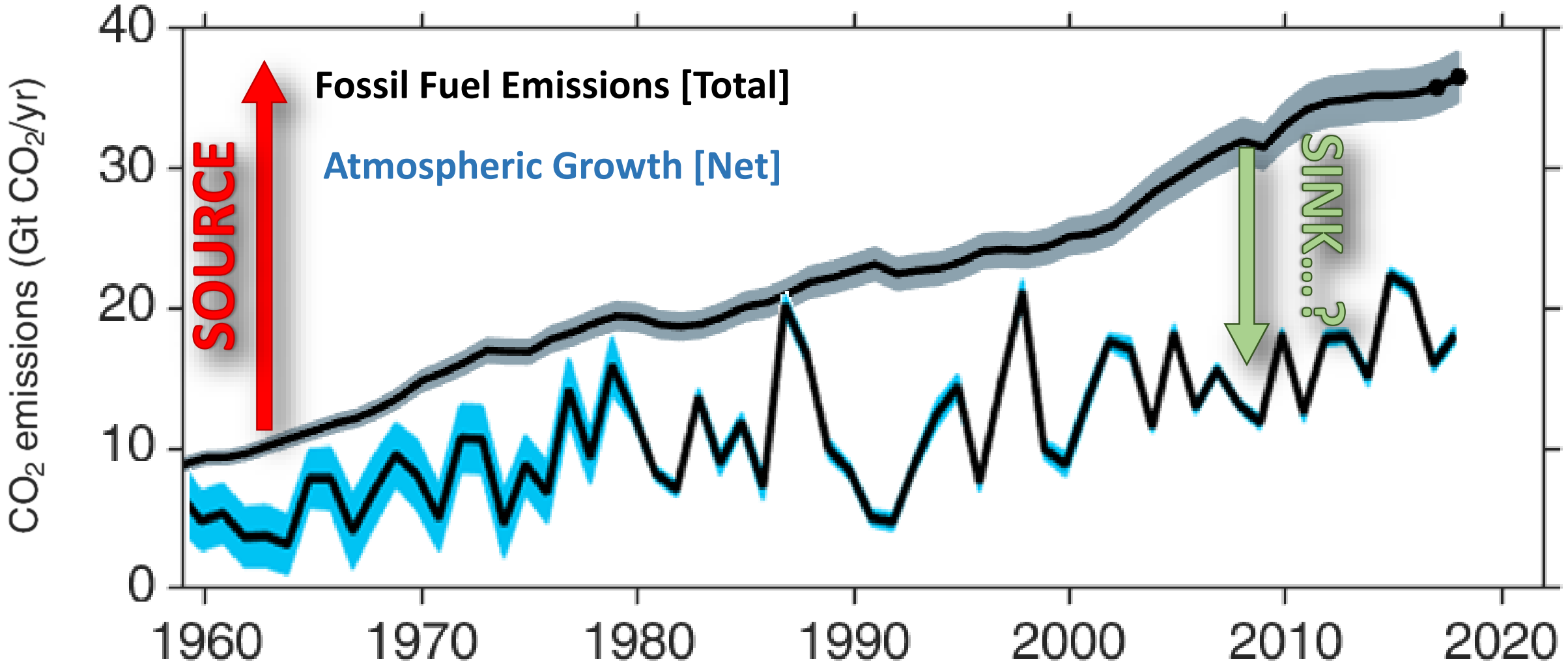
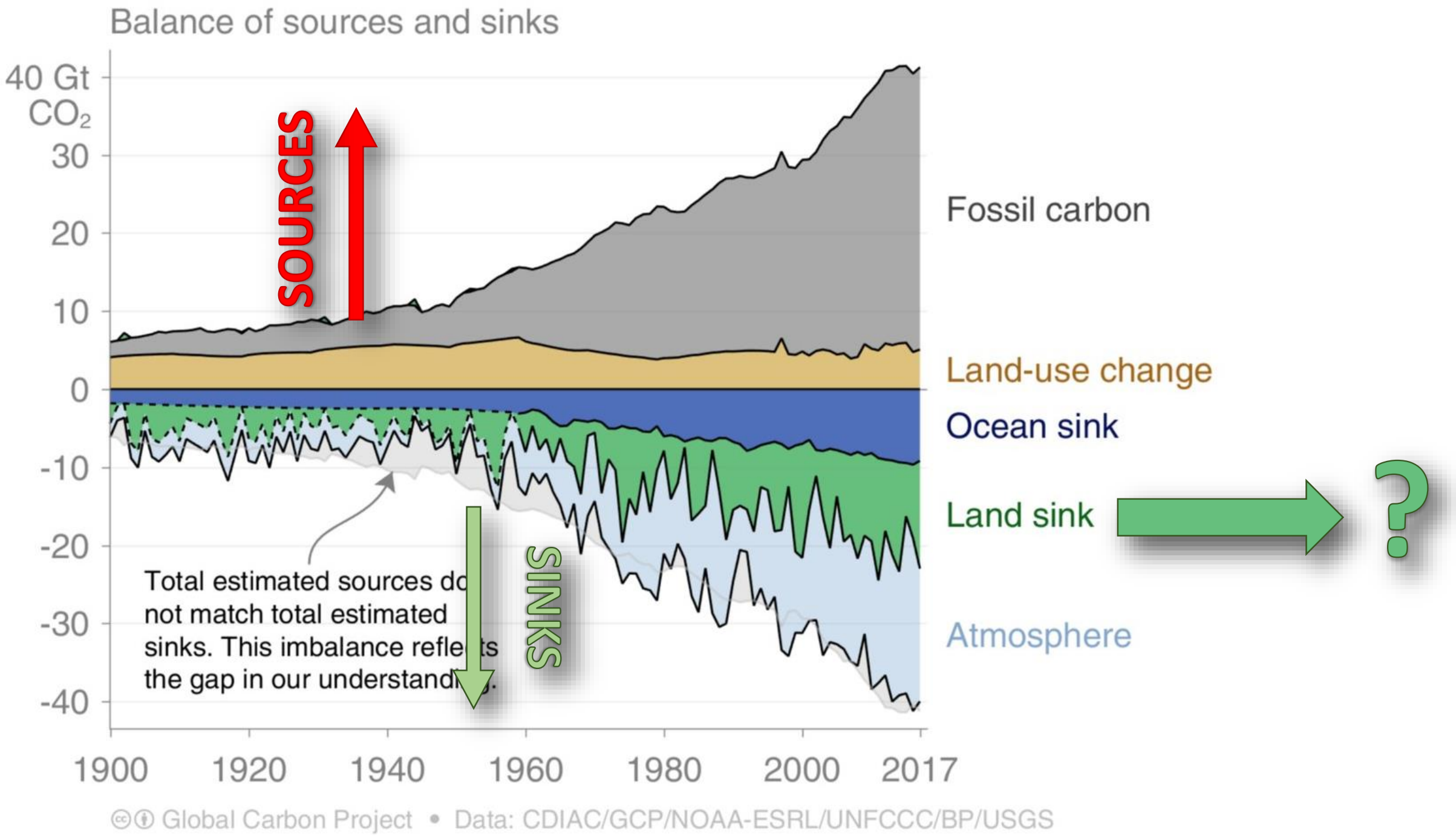

Carbon dioxide concentration at Mauna Loa Observatory
Full Record ending October 26, 2020
Latest CO_2 reading: 410.98 ppm
CO_2 Concentration (ppm)
420
410
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
SCRIPPS INSTITUTION OF OCEANOGRAPHY

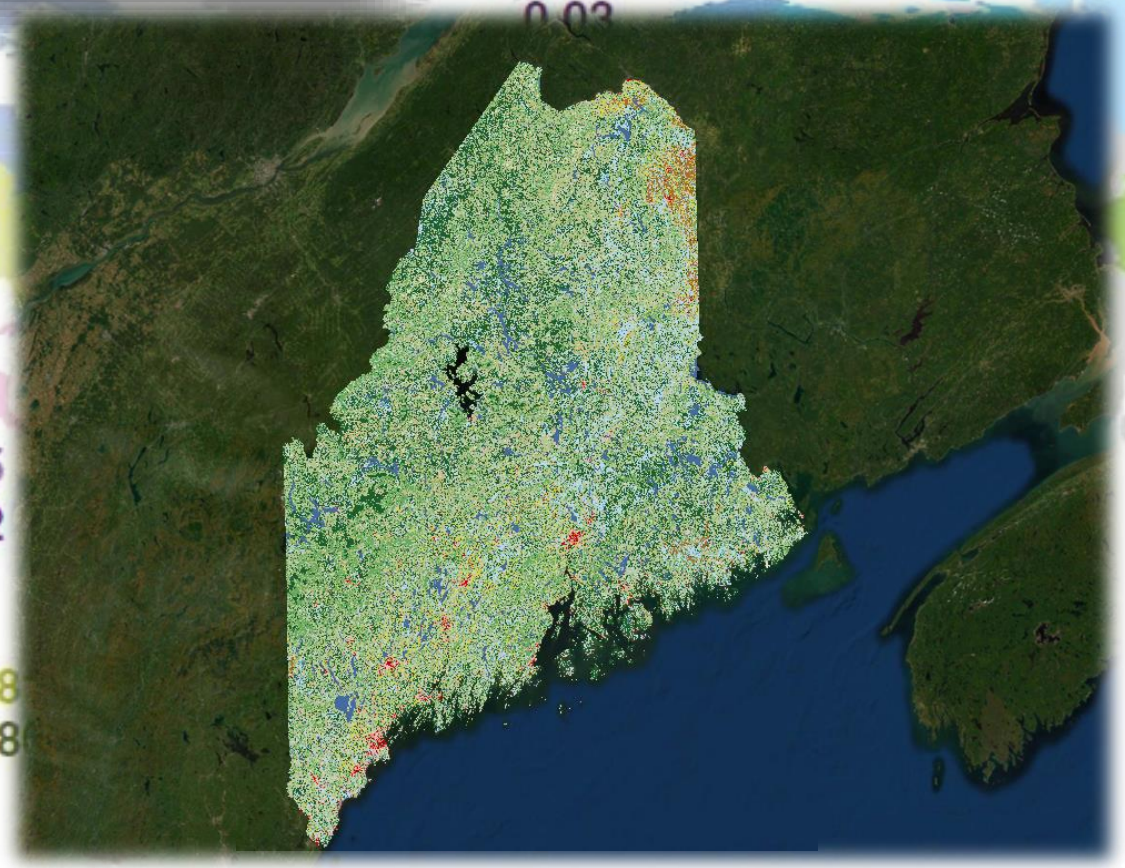

Fossil Fuel Emissions [Total]
Atmospheric Growth [Net]
SOURCE
SINK...?
CO_2 emissions (Gt CO_2/yr)
0
10
20
30
40
1960
1970
1980
1990
2000
2010
2020


Balance of sources and sinks
40 Gt
CO_2
30
20
10
0
-10
-20
-30
-40
SOURCES
SINKS
Total estimated sources do not match total estimated sinks. This imbalance reflects the gap in our understand
Fossil carbon
Land-use change
Ocean sink
Land sink
?
Atmosphere
1900
1920
1940
1960
1980
2000
2017
Global Carbon Project • Data: CDIAC/GCP/NOAA-ESRL/UNFCCC/BP/USGS

A Large and Persistent Carbon Sink in the World's Forests

Yude Pan,[1]* Richard A. Birdsey,[1] Jingyun Fang,[2,3] Richard Houghton,[4] Pekka E. Kauppi,[5] Werner A. Kurz,[6] Oliver L. Phillips,[7] Anatoly Shvidenko,[8] Simon L. Lewis,[7] Josep G. Canade

19 AUGUST 2011 VOL 333 SCIENCE www.sciencemag.org



0.07
0.03
0.03
0.01
0.26
0.26
0.18
0.24
0.14
0.18
0.07
0.06
0.14
0.12
0.97
0.85
0.53
0.59
0.65
0.42
0.8
0.8
0.06
0.06

Regions of the World

Other
- No Data/Other Countries

Tropical
- Asia
- Africa
- Americas

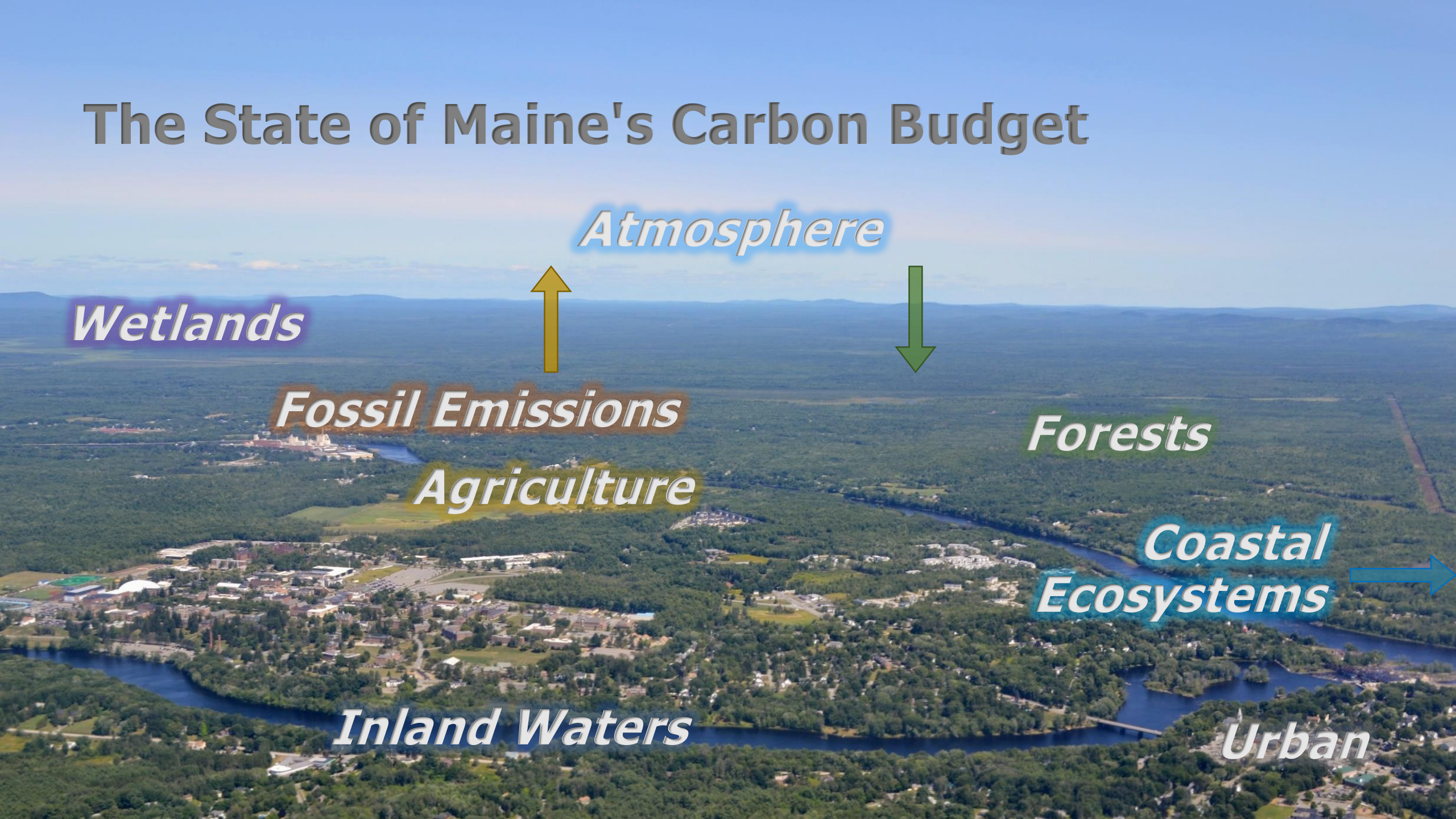
Temperate
- Continental US & S. Alaska
- Europe
- China
- Japan/Korea
- Australia/NZ

Boreal
- Canada
- N. Europe
- Asian Russia
- European Russia

- Forest Carbon Flux 1990-1999
- Forest Carbon Flux 2000-2007
- Tropical Regrowth Carbon Flux 1990-1999
- Tropical Regrowth Carbon Flux 2000-2007
- Tropical Gross Deforestation C Emissions 1990-1999
- Tropical Gross Deforestation C Emissions 2000-2007

The State of Maine's Carbon Budget (v1.0)

Xue Bai[1], Adam Daigneault[1], Ivan Fernandez[2], Jereme Frank[3], Daniel Hayes[1], Beverly Johnson[4], Xinyuan Wei[1], Aaron Weiskittel[5]


The State of Maine's Carbon Budget
Atmosphere
Wetlands
Fossil Emissions
Agriculture
Forests
Coastal Ecosystems
Inland Waters
Urban

Atmosphere

Trees take up C from the atmosphere through photosynthesis and adds it as biomass. As the C cycles through the ecosystem it is either returned to the atmosphere through decomposition or incorporated into the soil. In managed forests, live biomass is also removed in harvest and that C can be made into short- (e.g., pulp) or long- (e.g., sawlogs) term products. About 89% of Maine consists of forests (the most of any state), which account for the vast majority of C uptake and storage in this budget.

Decay

Net Uptake

Wood Products

Sawlogs

Landfill

Pulp

Forests

Live Biomass

Dead Biomass

Soils

Inland Waters

Sedimentation

Wood Harvest

Atmosphere

Carbon in crop residues can be incorporated into the soil, depending on management practices across the diversity of Maine's 7,600 farms. Livestock are a major source of the emissions from this sector.

Net Emissions

Agriculture

Emissions

Soils

Wood Products

Sawlogs

Landfill

Pulp

Forests

Live Biomass

Dead Biomass

Soils

Inland Waters

Sedimentation

Wood Harvest

Atmosphere

In built environments, the C stored in trees, gardens, lawns, and wooden structures from residential areas and parks are increasingly important in keeping C out of the atmosphere.

Net Uptake

Wood Products

Sawlogs

Landfill

Pulp

Forests

Live Biomass

Dead Biomass

Soils

Agriculture

Emissions

Soils

Urban

Live Biomass

Soils

Inland Waters

Sedimentation

Wood Harvest

Atmosphere

There are more than 277,000 acres of wetlands in Maine, including bogs and fens where C is stored in saturated organic (e.g., peat) and mineral soils.

Net Uptake

Net Emissions

Net Uptake

Wood Products

Sawlogs

Landfill

Pulp

Forests

Live Biomass

Dead Biomass

Soils

Wetlands

Live Biomass

Soils

Agriculture

Emissions

Soils

Urban

Live Biomass

Soils

Inland Waters

Sedimentation

Wood Harvest

Atmosphere

Inland Waters

Carbon is transported from land through Maine's rivers to the ocean. Some of that C is buried in lake sediments, while much of it outgasses from the water column.

Coastal Ecosystems

"Blue Carbon" is found in salt marshes and eelgrass ecosystems, which have high rates of C storage in their sediments despite their relatively small area in Maine.

Outgassing

Forests

Live Biomass

Dead Biomass

Soils

Wetlands

Live Biomass

Soils

Agriculture

Emissions

Soils

Urban

Live Biomass

Soils

Coastal Waters

Live Biomass

Soils

Inland Waters

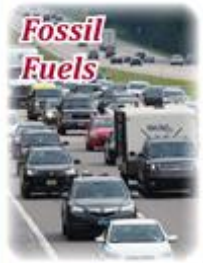
Sedimentation

Table 1. Absolute and relative estimates of land area (millions of acres) and carbon (Megagrams) as well as carbon density (Mg C per acre) in 2016 by primary land type in Maine

	Area		Carbon		
Land Type	**M acres**	**% Total**	**Stock (Mg C)**	**% Total**	**Density (Mg C/acre)**
Forest	17.30	87.6%	2,071,219,199	88.7%	122
Ag (soil only)	1.25	6.3%	96,303,017	4.1%	77
Wetland	0.28	1.4%	71,229,883	3.1%	257
Salt Marshes (upper 1 m)	0.02	0.1%	2,518,500	0.1%	140
Seagrasses (upper 1 m)	0.03	0.2%	1,625,600	0.1%	51
Urban	0.87	4.4%	91,015,658	3.9%	105
Total	**19.75**	**100.0%**	**2,333,911,856**	**100.0%**	**118**

Compiled by the Forest Climate Change Initiative, Center for Research on Sustainable Forests at the University of Maine.

Atmosphere



The plot below shows C emissions over time (since 1990) from the major sources of fossil fuel combustion in Maine. Carbon emissions from fossil fuel combustion in Maine peaked in 2002-04, and have been declining by ~3% per year since. Despite the decline, transportation emissions have maintained a steady pace and currently account for more than half of total emissions.

Fossil Fuels

Transportation

Residential

Industrial

Electric Power

Commercial

Waste

Wood Products

Sawlogs

Landfill

Pulp

Forests

Live Biomass

Dead Biomass

Soils

Wetlands

Live Biomass

Soils

Agriculture

Emissions

Soils

Urban

Live Biomass

Soils

Coastal Waters

Live Biomass

Soils

Inland Waters

Sedimentation

Net Uptake

Net Emissions

Net Uptake

Outgassing

Wood Harvest

1,000s metric tons of C per year

Atmosphere
5,125

Emissions

4,897

Net Emissions

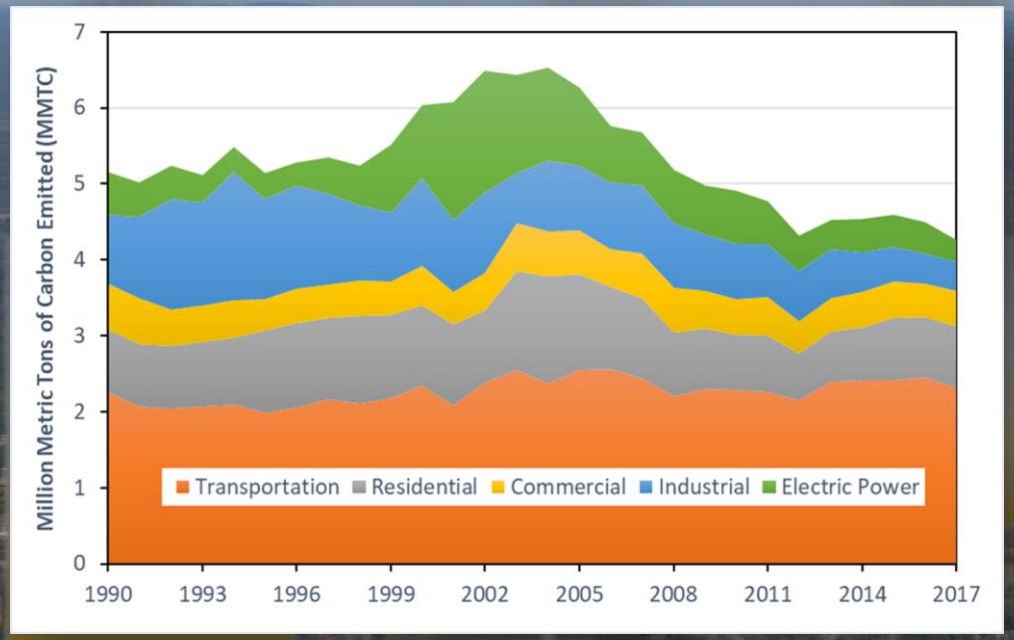
228

Uptake

Outgassing

Fossil Fuels

Transportation
-2,333
Residential
-775
Industrial
-658
Electric Power
-545
Commercial
-490
Waste
-95



Agriculture

Emissions
-172
Soils
-88

Urban

Live Biomass

Soils

Coastal Waters

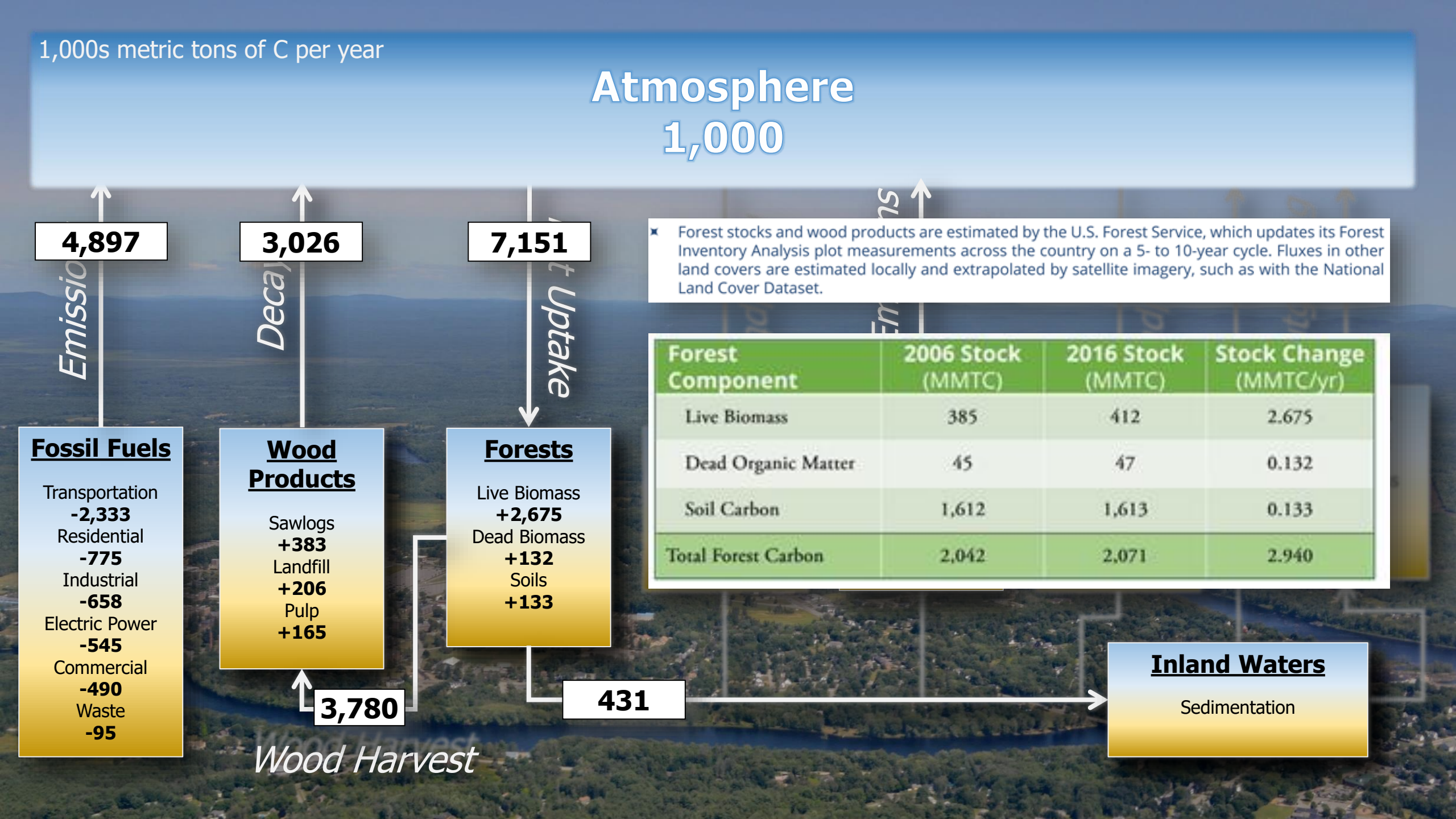
Live Biomass

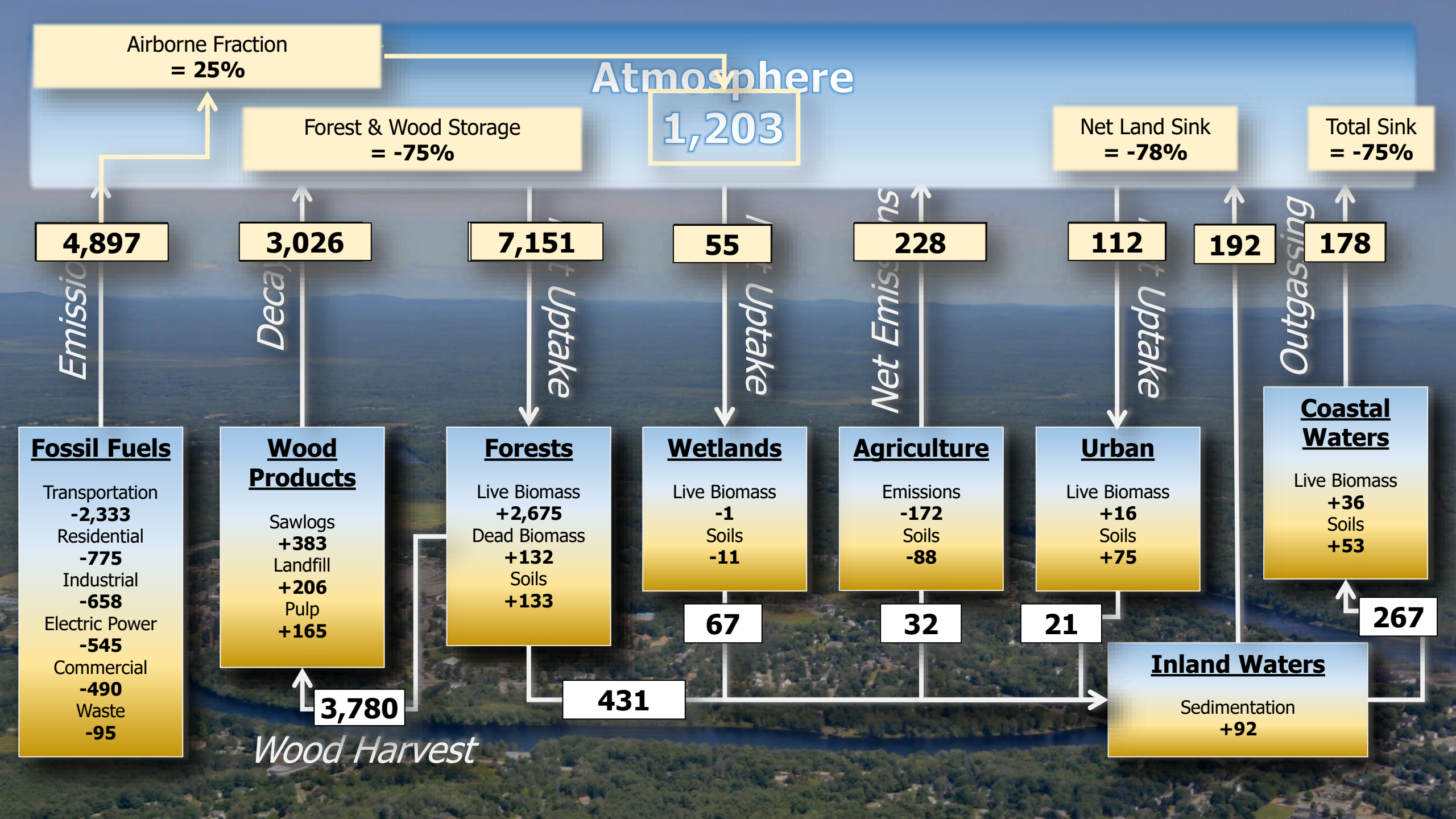
Soils

Inland Waters

Sedimentation

- The U.S. Energy Information Administration reports annual estimates of fossil fuel emissions by energy-consuming sector in each state. Agricultural emissions and other sources are compiled in the U.S. Environmental Protection Agency's National Greenhouse Gas Inventory and Reporting.

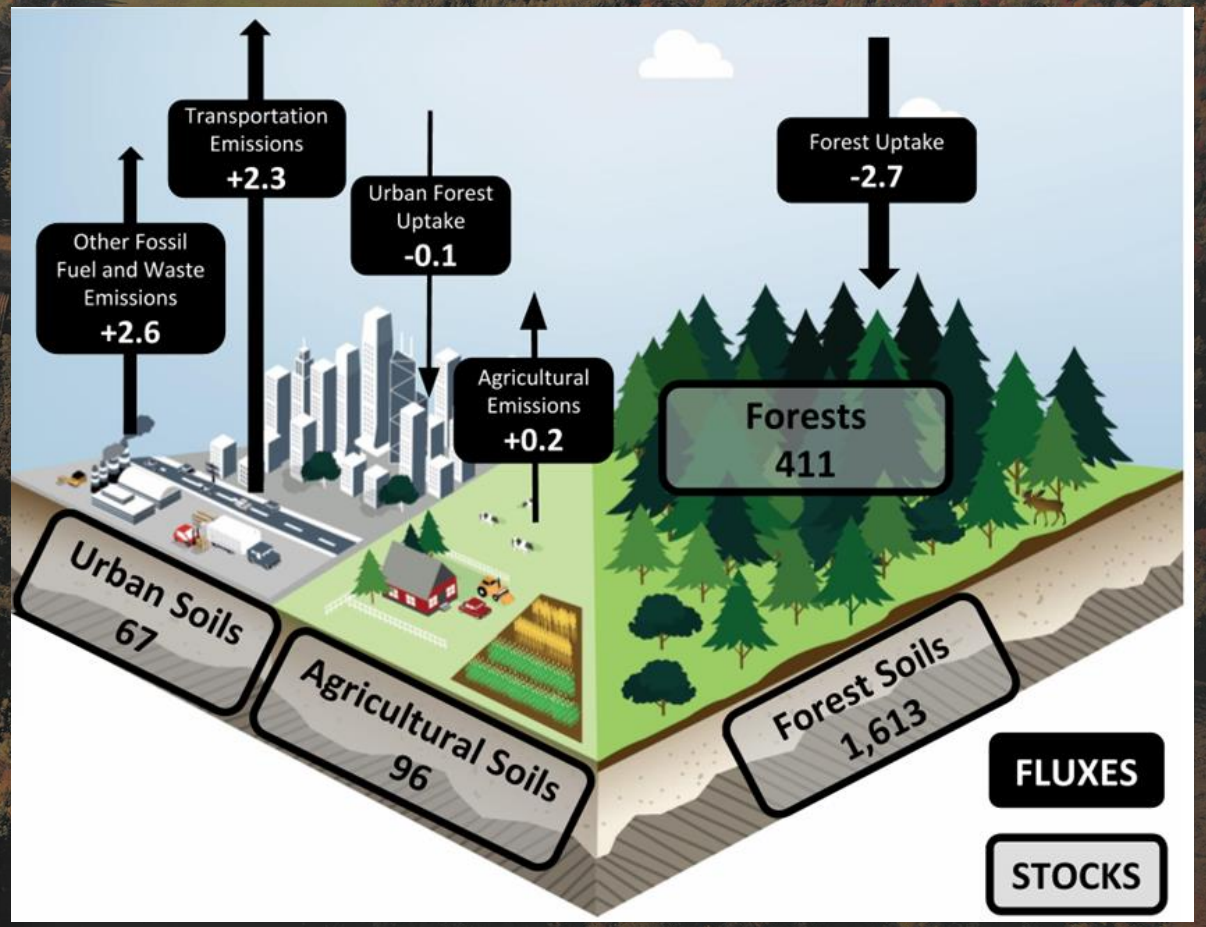

1,000s metric tons of C per year
Atmosphere
1,000
4,897
3,026
7,151
Emissions
Decay
Net Uptake
Fossil Fuels
Transportation
-2,333
Residential
-775
Industrial
-658
Electric Power
-545
Commercial
-490
Waste
-95
Wood Products
Sawlogs
+383
Landfill
+206
Pulp
+165
Forests
Live Biomass
+2,675
Dead Biomass
+132
Soils
+133
3,780
Wood Harvest
431
Inland Waters
Sedimentation
Forest stocks and wood products are estimated by the U.S. Forest Service, which updates its Forest Inventory Analysis plot measurements across the country on a 5- to 10-year cycle. Fluxes in other land covers are estimated locally and extrapolated by satellite imagery, such as with the National Land Cover Dataset.
Forest Component | 2006 Stock (MMTC) | 2016 Stock (MMTC) | Stock Change (MMTC/yr)
Live Biomass | 385 | 412 | 2.675
Dead Organic Matter | 45 | 47 | 0.132
Soil Carbon | 1,612 | 1,613 | 0.133
Total Forest Carbon | 2,042 | 2,071 | 2.940

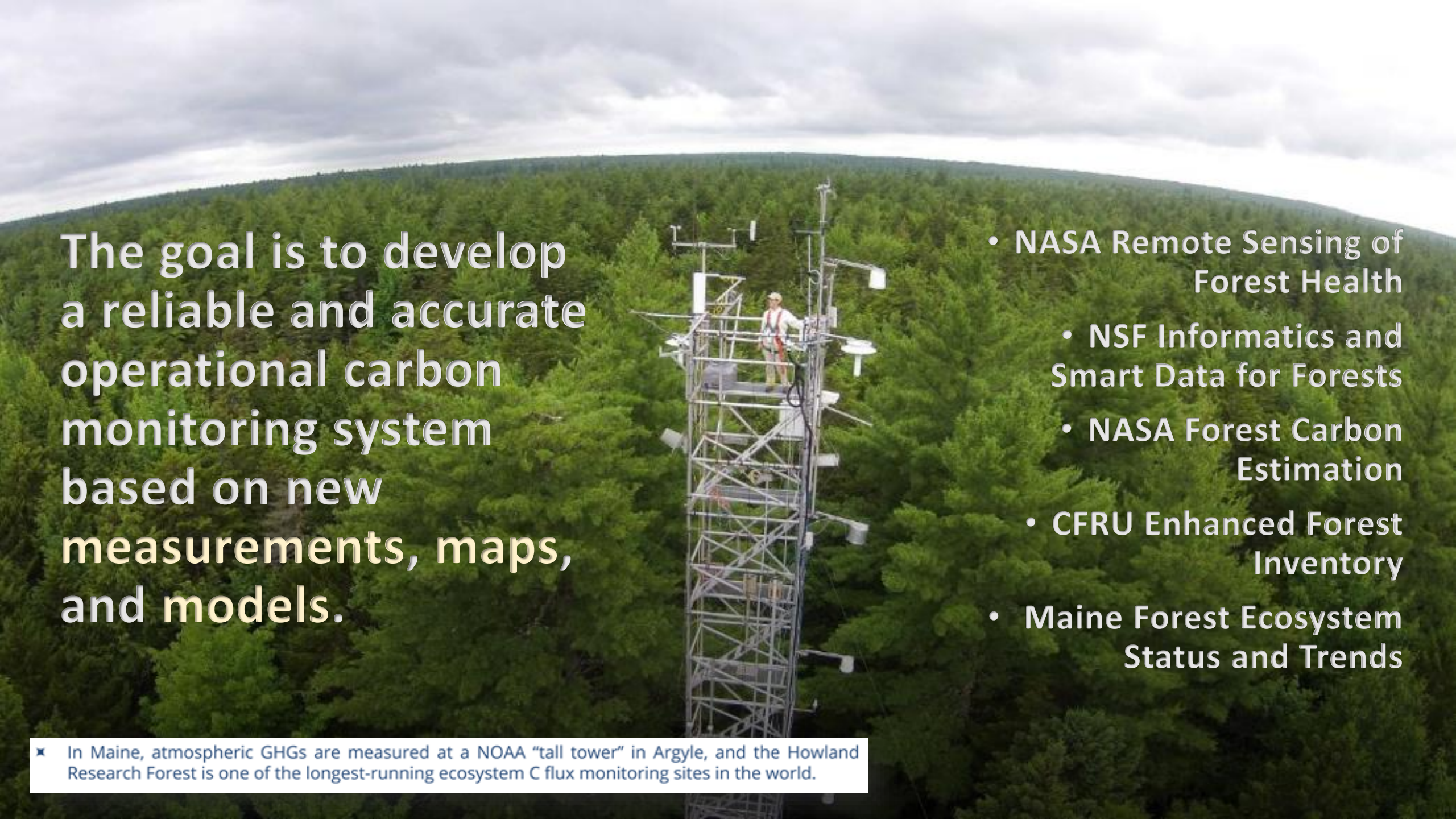

Airborne Fraction
= 25%
Atmosphere
1,203
Forest & Wood Storage
= -75%
Net Land Sink
= -78%
Total Sink
= -75%
4,897
3,026
7,151
55
228
112
192
178
Emissions
Decay
Net Uptake
Net Uptake
Net Emissions
Net Uptake
Outgassing
Fossil Fuels
Transportation
-2,333
Residential
-775
Industrial
-658
Electric Power
-545
Commercial
-490
Waste
-95
Wood Products
Sawlogs
+383
Landfill
+206
Pulp
+165
Forests
Live Biomass
+2,675
Dead Biomass
+132
Soils
+133
Wetlands
Live Biomass
-1
Soils
-11
Agriculture
Emissions
-172
Soils
-88
Urban
Live Biomass
+16
Soils
+75
Coastal Waters
Live Biomass
+36
Soils
+53
67
32
21
267
3,780
431
Wood Harvest
Inland Waters
Sedimentation
+92

The State of Maine's Carbon Budget: Key Findings

Key Findings

- GHG emissions in Maine are dominated by burning fossil fuels, primarily from the transportation sector, but with a sharp decline in electric power emissions over the last decade.
- Carbon 'offsets' are estimated as 55% for forest growth and 75% for the total annual C cycle.
- Critical uncertainties in the budget arise from undersampled or unknown components. Improved assessments require advances in stock quantification and flux monitoring.





The goal is to develop a reliable and accurate operational carbon monitoring system based on new measurements, maps, and models.

- NASA Remote Sensing of Forest Health
- NSF Informatics and Smart Data for Forests
- NASA Forest Carbon Estimation
- CFRU Enhanced Forest Inventory
- Maine Forest Ecosystem Status and Trends

In Maine, atmospheric GHGs are measured at a NOAA "tall tower" in Argyle, and the Howland Research Forest is one of the longest-running ecosystem C flux monitoring sites in the world.

Thank You!

daniel.j.hayes@maine.edu