Tidally-restricted coastal wetlands as a hotspot for carbon dioxide and methane emissions, and as a potent and untapped opportunity for anthropogenic emissions reductions

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photo: S. Baldwin

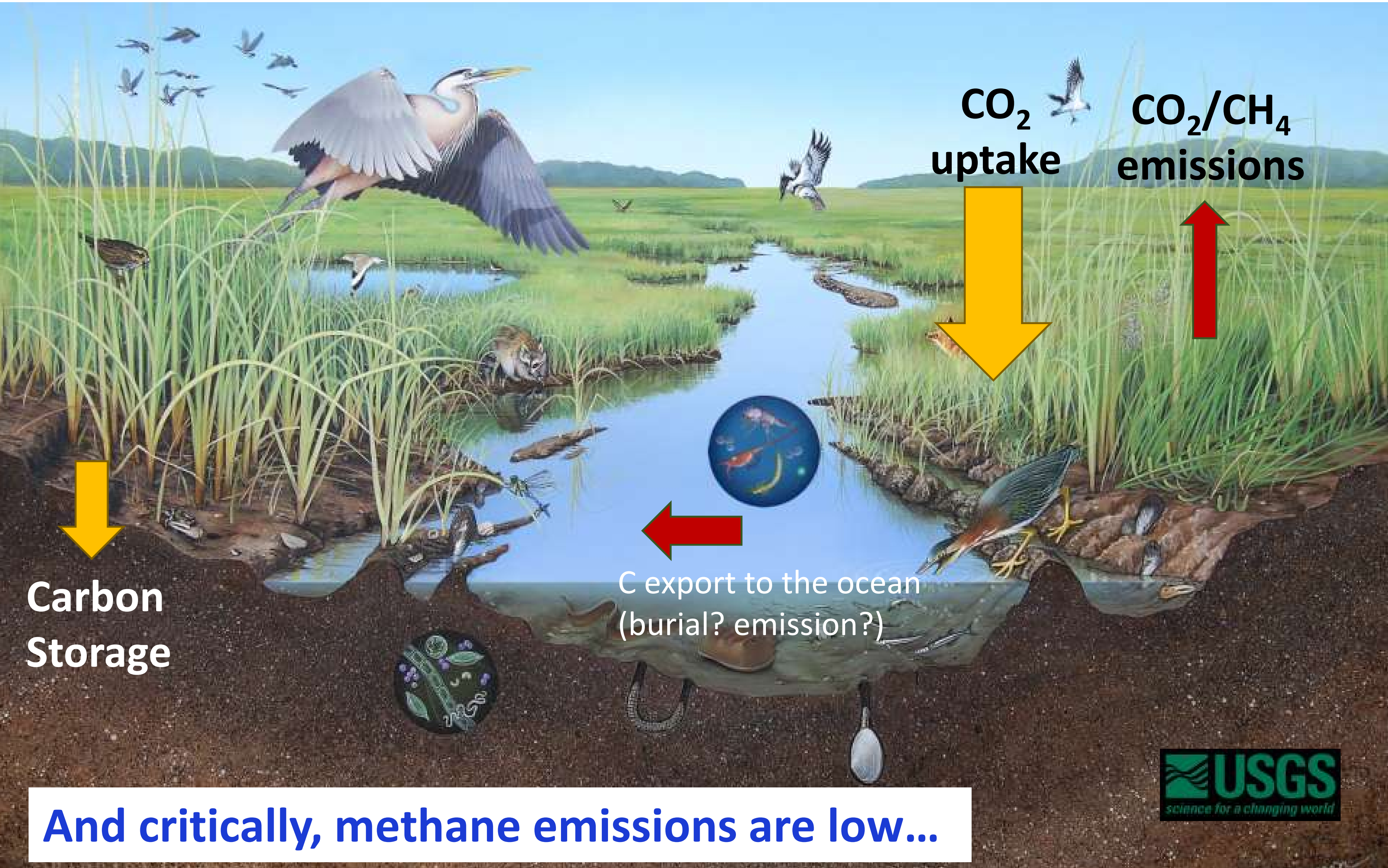
Bottom line conclusions:

- For several centuries it has been a worldwide practice to both impound and drain coastal wetlands.
- Those altered wetlands produce substantial CH_4 and CO_2 emissions, equivalent to emissions from millions of automobiles.
- At present, there are no incentives to reduce the emissions, and so the situation is analogous to setting thousands of fires, allowing them to burn for decades to centuries, and then ignoring them in our attempts to reduce emissions.
- Inventorying the emissions and crediting reduction in the emissions can incentivize a new and potent method for emissions reduction at local, state and national levels, while simultaneously encouraging wetland restoration and improvements in coastal resilience.

The Rest of the Story

How do salt marshes interact with climate? Salt marsh plants remove carbon dioxide from the atmosphere.

Some of the carbon is stored for centuries as soil carbon.



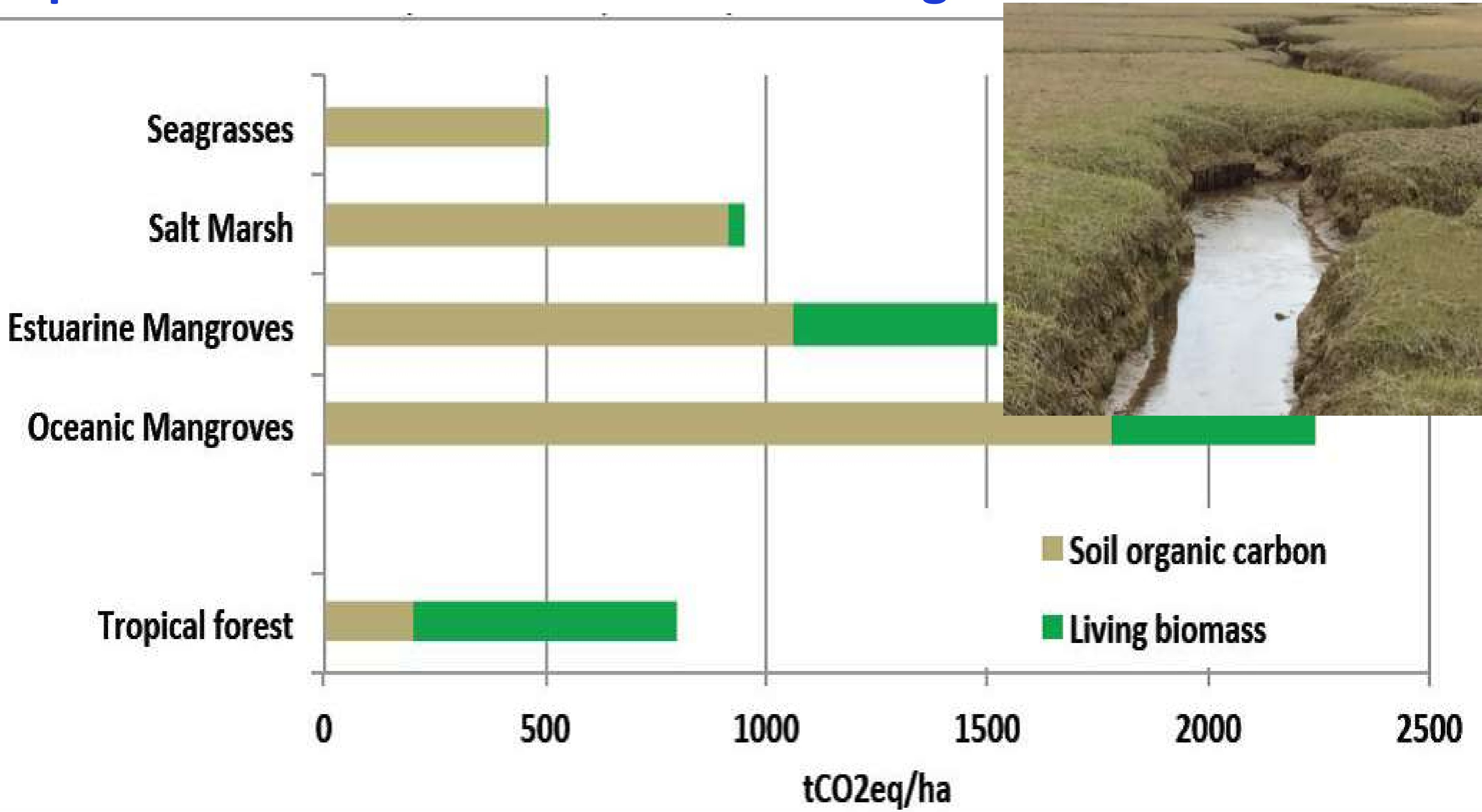
And critically, methane emissions are low…

Salt marshes rapidly store carbon because they grow vertically at about the same rate as sea level rise. The soil is composed of plant roots and trapped sediment, and thus large carbon stores accumulate over many centuries, keeping CO_2 out of the atmosphere:

This benefit to society sometimes referred to as "Blue Carbon"

Photos M. Gonneea

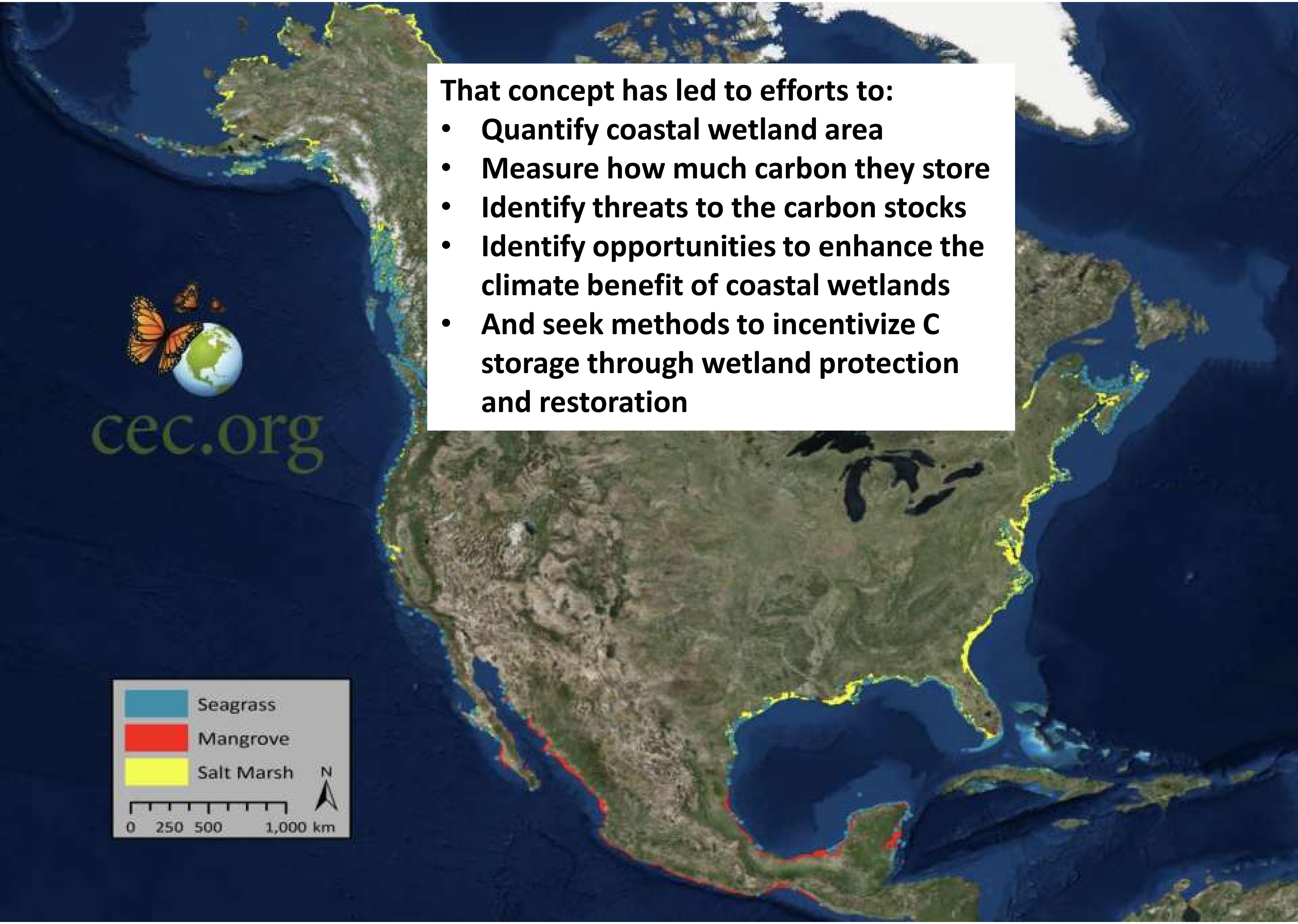
C storage rate, and magnitude of C stocks, are large compared to forests. This has led to the idea that we can protect and restore wetlands with a goal to store carbon.



Carbon Stocks (tonnes CO_2equivalents per hectare)

That concept has led to efforts to:

- Quantify coastal wetland area
- Measure how much carbon they store
- Identify threats to the carbon stocks
- Identify opportunities to enhance the climate benefit of coastal wetlands
- And seek methods to incentivize C storage through wetland protection and restoration



Bringing Wetlands to Market

mproved Understanding of C Dynamics and Biogeochemical Processes

New Tools for Managers and Policymakers

Innovative Science

- GHG Budgets
- Nitrogen Influence
- Habitat relationships

Field Investigations & Lab Analyses

Predicting C Storage

How does GHG flux and carbon storage change under different env. conditions?

Develop User-Friendly Model

Carbon Markets & Financing

Address a main barrier for wetlands restoration & conservation

Wetlands Carbon Offset Methodology

Economic Analysis

Is a Carbon Market Project Worth It?

Local Case Study – How much are methane benefits worth?

COLLABORATION WITH END USERS

National Estuarine Research Reserve System Science Collaborative

Courtesy of T-M. Rogers

An issue identified within the BWM project is that wetland response to tidal restriction and restoration, in terms of carbon storage and greenhouse gas emissions, is not well-known, but is of critical importance…

Identified Tidal Restrictions in Buzzards Bay, Mass

GEOGRAPHY

Nearly 600 in state of Massachusetts alone

The first reason that it is an important question is that tidally-restricted wetlands are widespread in Massachusetts and throughout the world. The second reason is that gas emission rates in degraded wetlands may be quite high...

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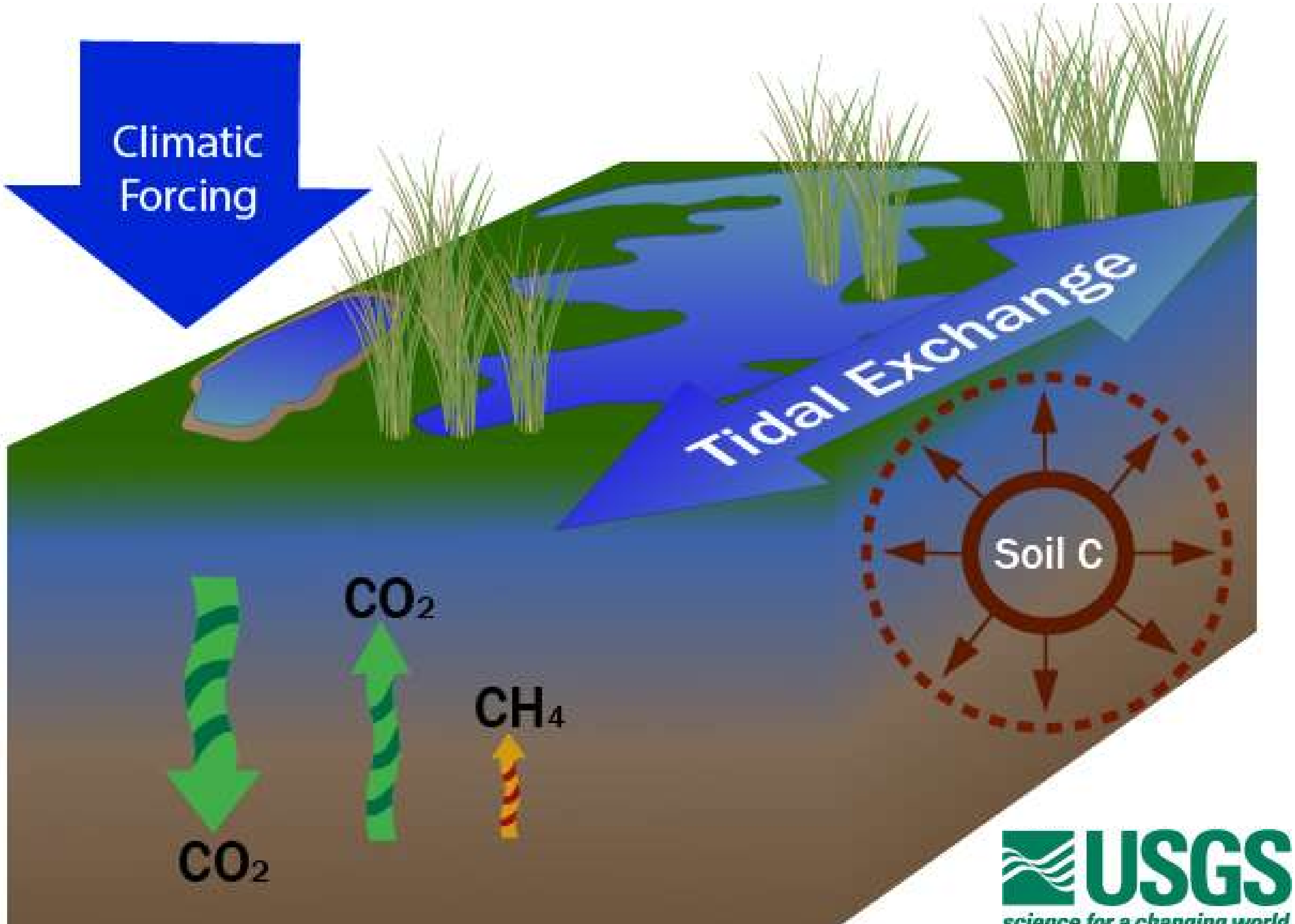
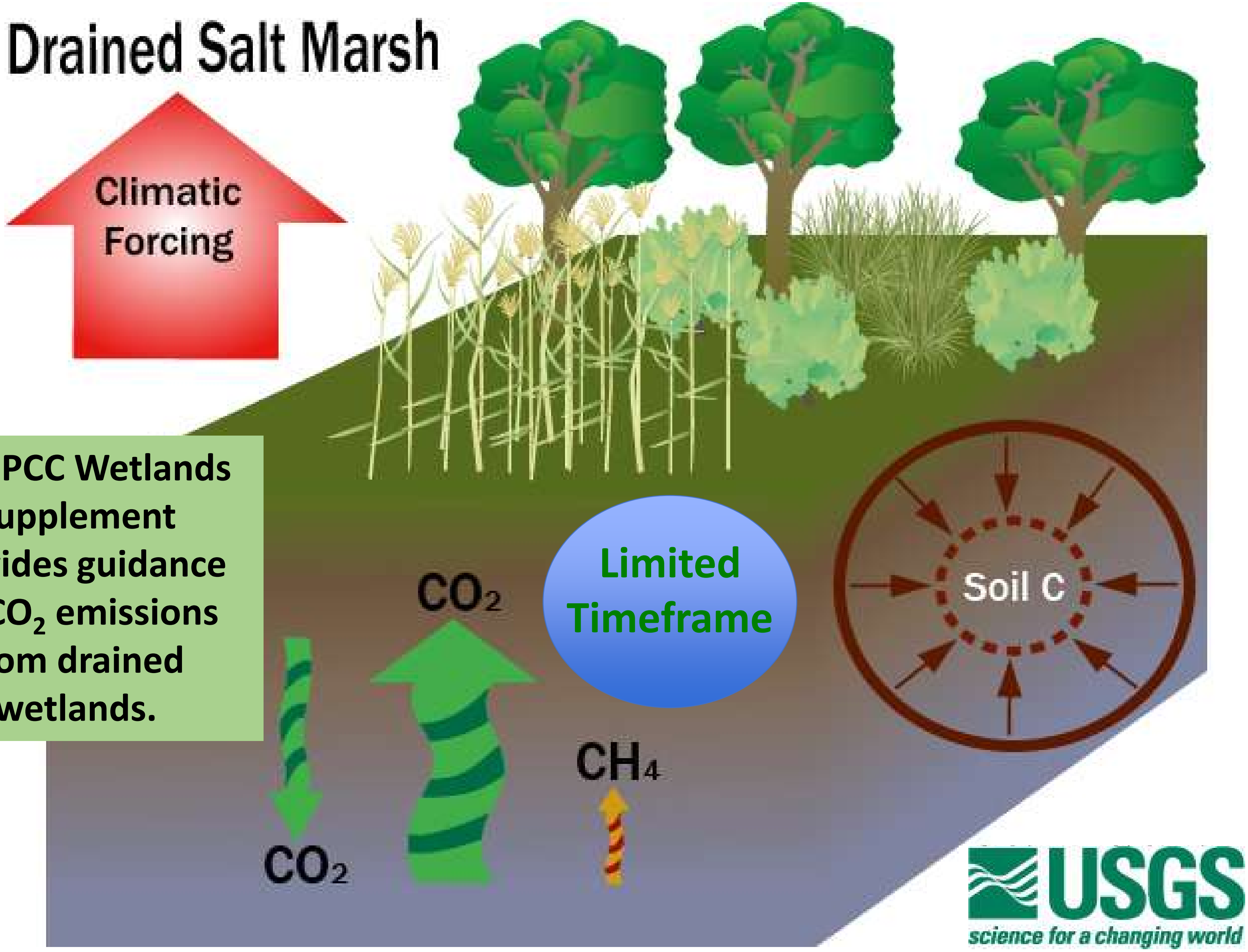
Salt Marsh with Natural or Restored Tidal Flow



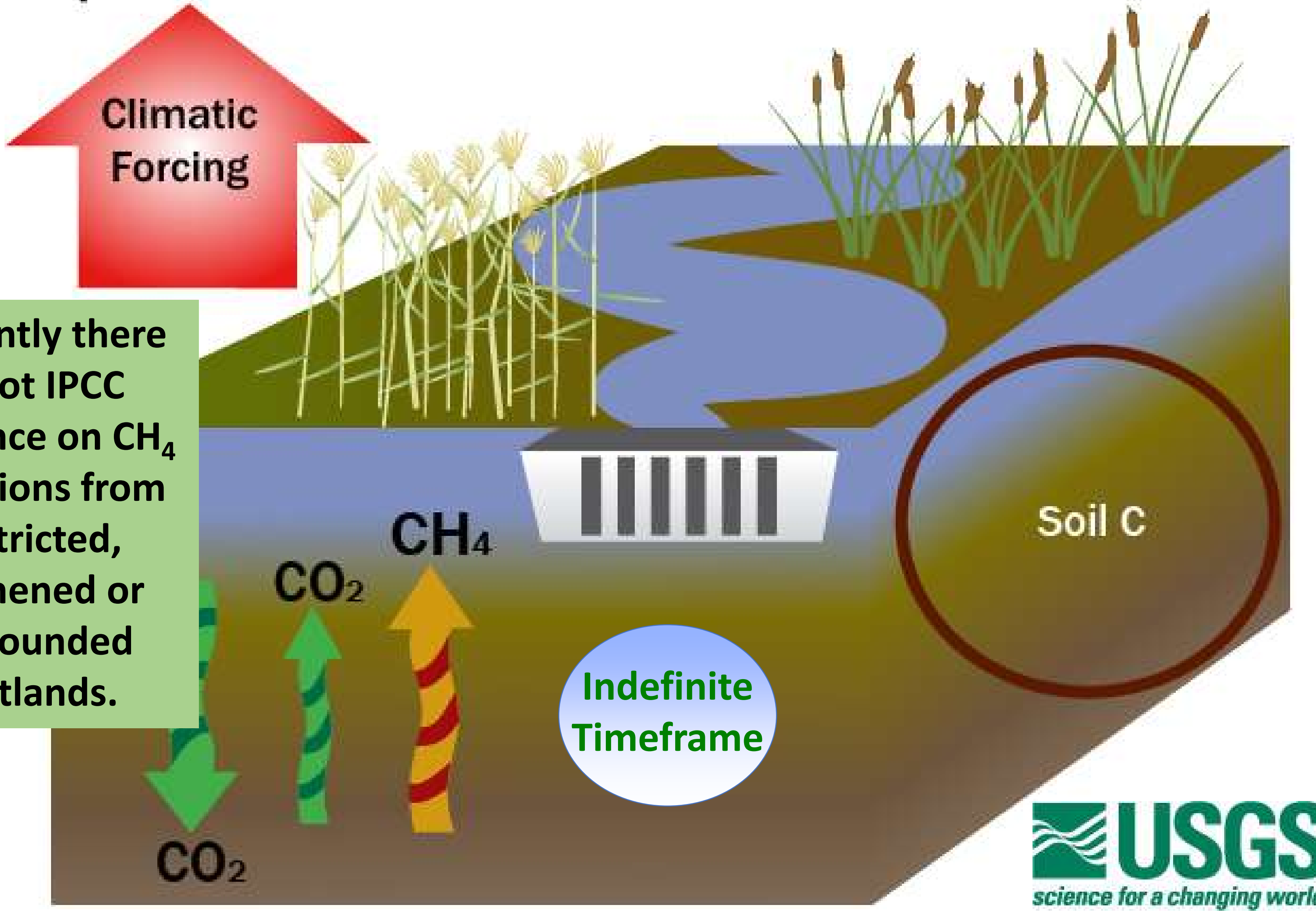
Kroeger et al. 2017, Scientific Reports 7, Article number 11914



The IPCC Wetlands Supplement provides guidance on CO_2 emissions from drained wetlands.

Kroeger et al. 2017, Scientific Reports 7, Article number 11914

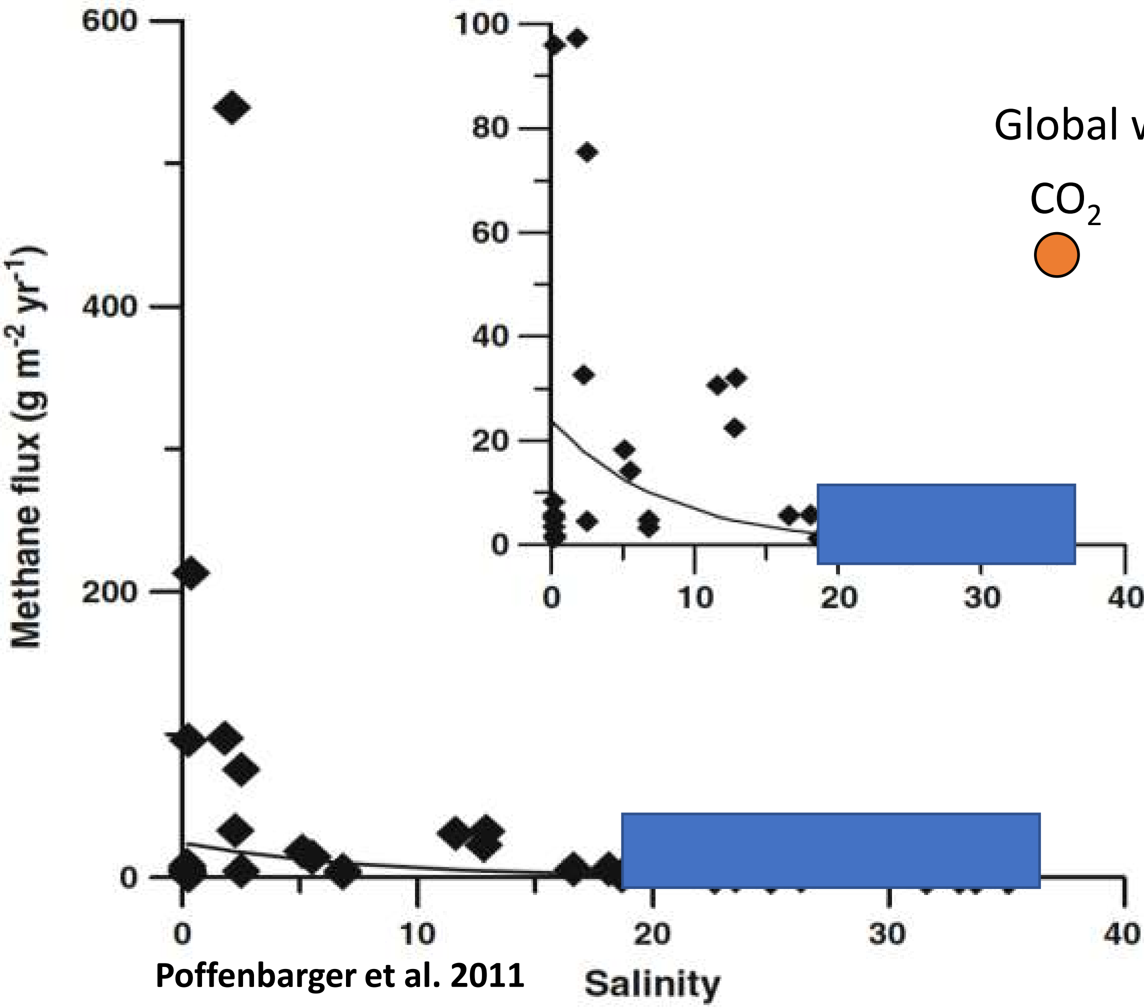
Impounded Salt Marsh With Restricted Tidal Flow



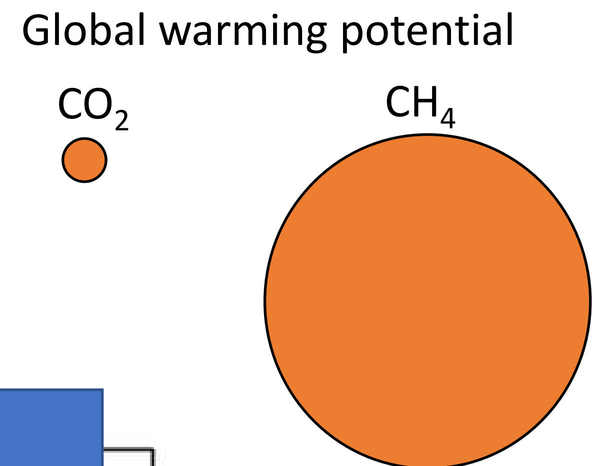
Presently there is not IPCC guidance on CH_4 emissions from restricted, freshened or impounded wetlands.

Kroeger et al. 2017, Scientific Reports 7, Article number 11914

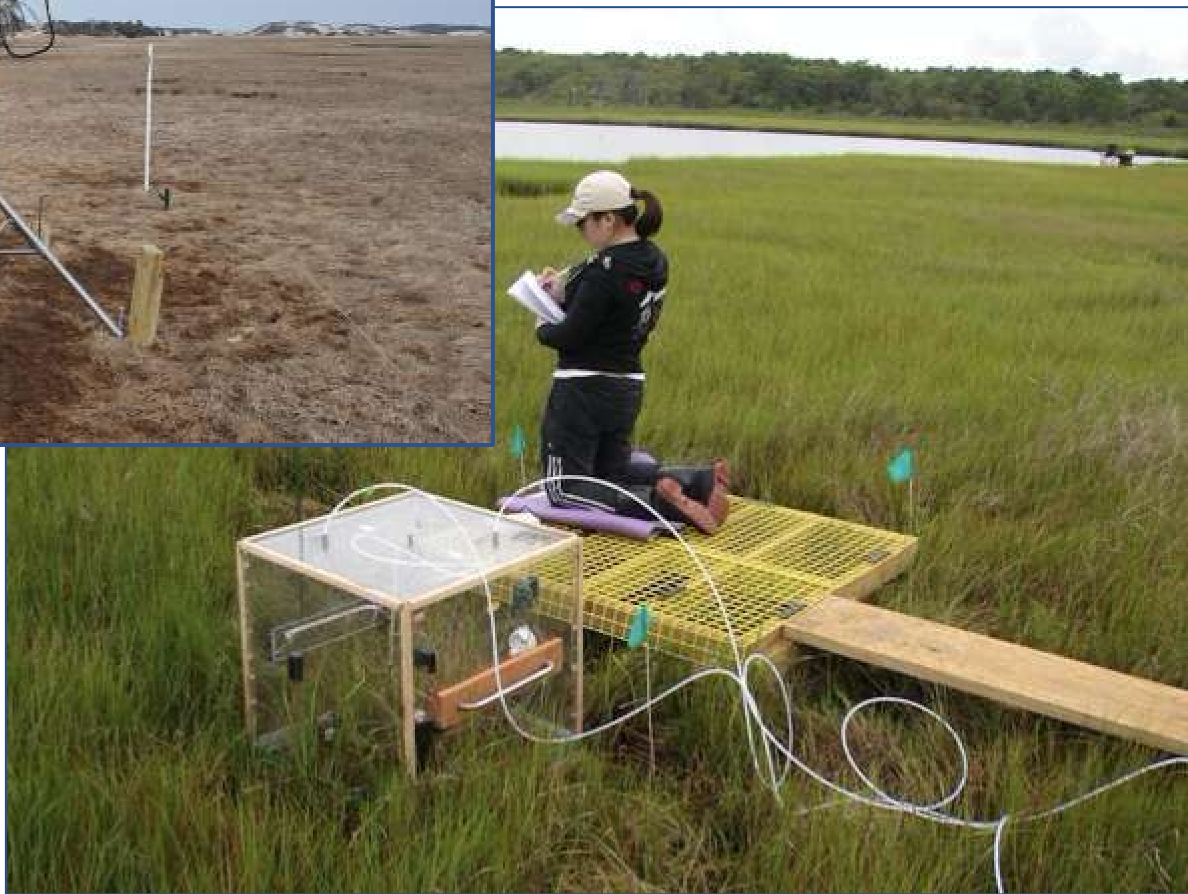
Methane emissions are typically very low at higher salinity, but if we cause freshening by impounding fresh water, in many cases methane emissions are likely to increase.

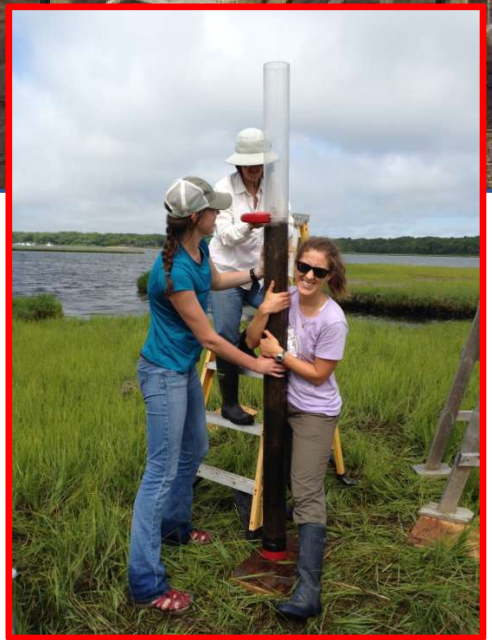


Poffenbarger et al. 2011

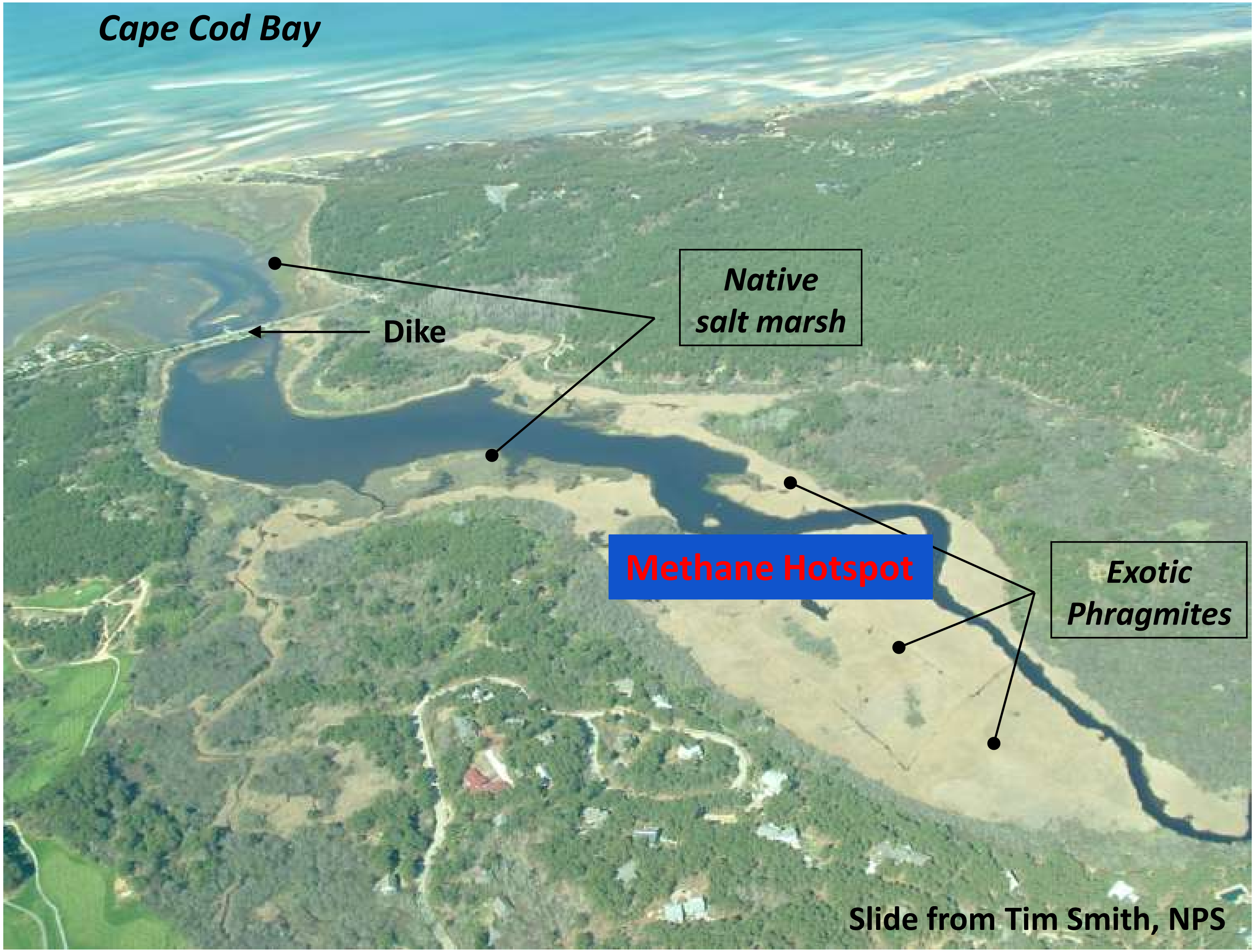


To answer the questions about the effects of tidal restriction and restoration on carbon dioxide uptake or emission, and changes in methane emissions, we are measuring gas fluxes, changes in soil carbon, and transport of carbon in water in a series of tidally-restricted and restored sites along Cape Cod Bay.





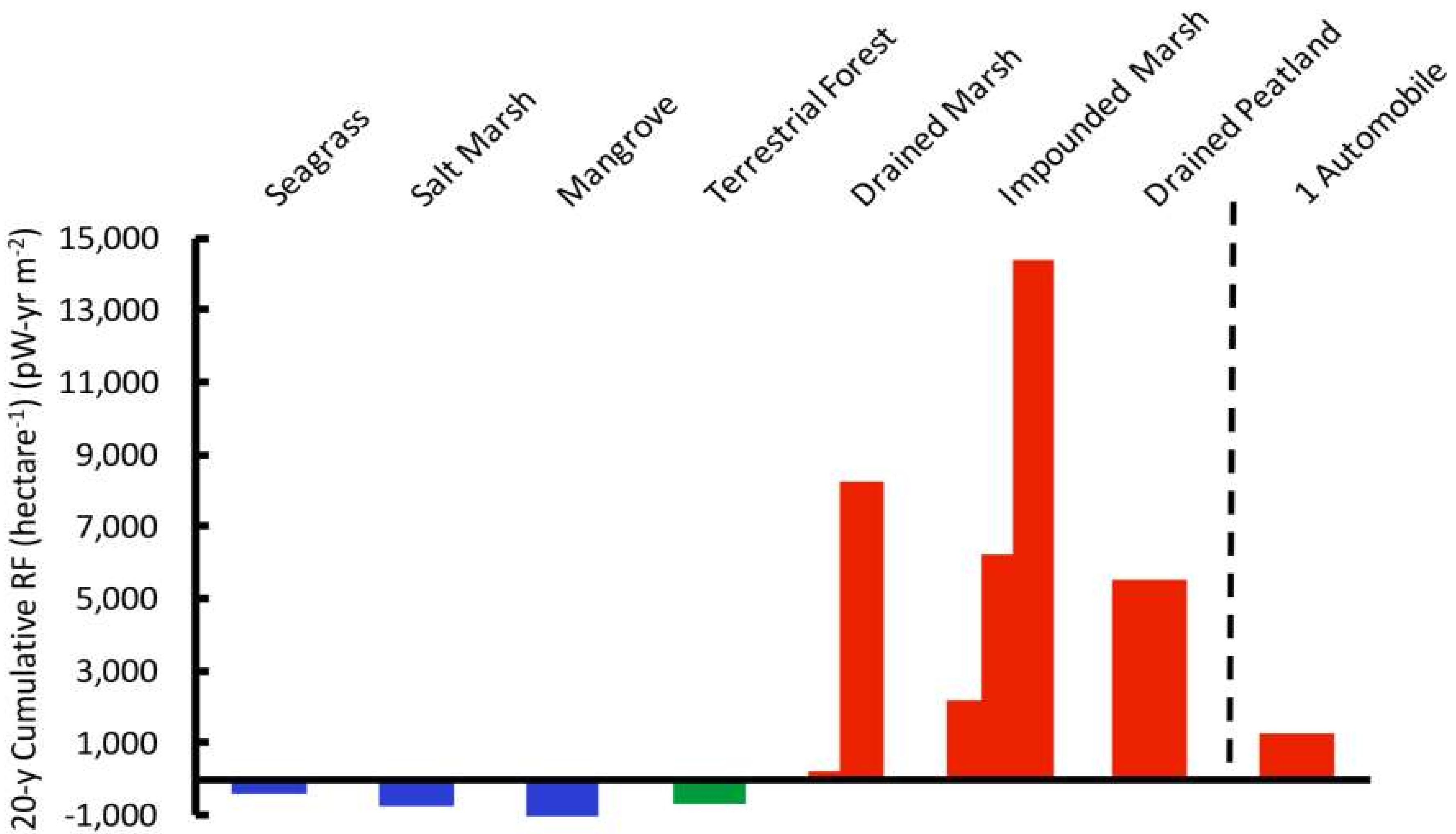
An important study site is the Herring River, Cape Cod National Seashore: ~1000 acres of tidally restricted wetland, that is proposed for restoration, and contains both drained and freshened/impounded former salt marsh.



Are the enhanced emissions in tidally-restricted wetlands significant?

- **Modeled radiative forcing indicates intense emissions per acre**

20-year Cumulative Radiative Forcing, Tier 1 EF



Kroeger et al. 2017, Scientific Reports 7, Article number 11914

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And they are widespread, covering a substantial area:

- ~2,700 km^2 impounded, freshened wetland on US Atlantic coast
- 28,000 to 145,000 tonnes enhanced CH_4 emissions per year
- Over a 20 yr period, radiative forcing equivalent to 20 yrs emissions from 0.6 to 3.1 M automobiles
- Significant potential for emissions reductions
- Working to include in the Inventory of US GHG Emissions and Sinks, as well as analysis of C market feasibility in Herring River

Kroeger et al. 2017

Location	Tidal Wetland in Study Area (km^2)	Wetland Area Affected (km^2)	Fraction of wetland area affected (%)
Transportation-Related Restrictions:			
Southern Maine[24]	32	9	28
New Hampshire[24]	26	5	20
Massachusetts[46]	212	58	27
North Shore[47]	113	6	5
Cape Cod[48]	70	20	28
Buzzards Bay[49]		33	
Rhode Island[52]	16	11	70
Total Transportation	286	84	29
Diked and Impounded for Waterfowl or Mosquito Management:			
N. Carolina[9]	643	21	3
S. Carolina[9]	2,041	285	14
Georgia[9]	1,590	32	2
Florida (Atlantic)[9]	778	143	18
Total Diked	5,053	482	10
Total impounded tidal wetlands U.S. Atlantic coast, Transportation + Diked	9,710[10]	3,787	39
Total area impounded and freshened:			
U.S. Atlantic coast	9,710	2,650	27

The good news is that we know how to restore the wetlands. In addition to restoring threatened salt marsh habitat and enhancing resilience, we can expect to reduce greenhouse gas emissions as well: Preliminary calculations indicate that in the first 40 years following restoration of the Herring River, GHG benefits will be equivalent to taking 276 cars off the road for 40 years. That benefit expected to increase during the decades beyond 40 years.

CONCEPTUAL RENDERING OF BRIDGE

Acknowledgements…

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  - **National Park Service**
  - **Friends of Herring River**


Questions?
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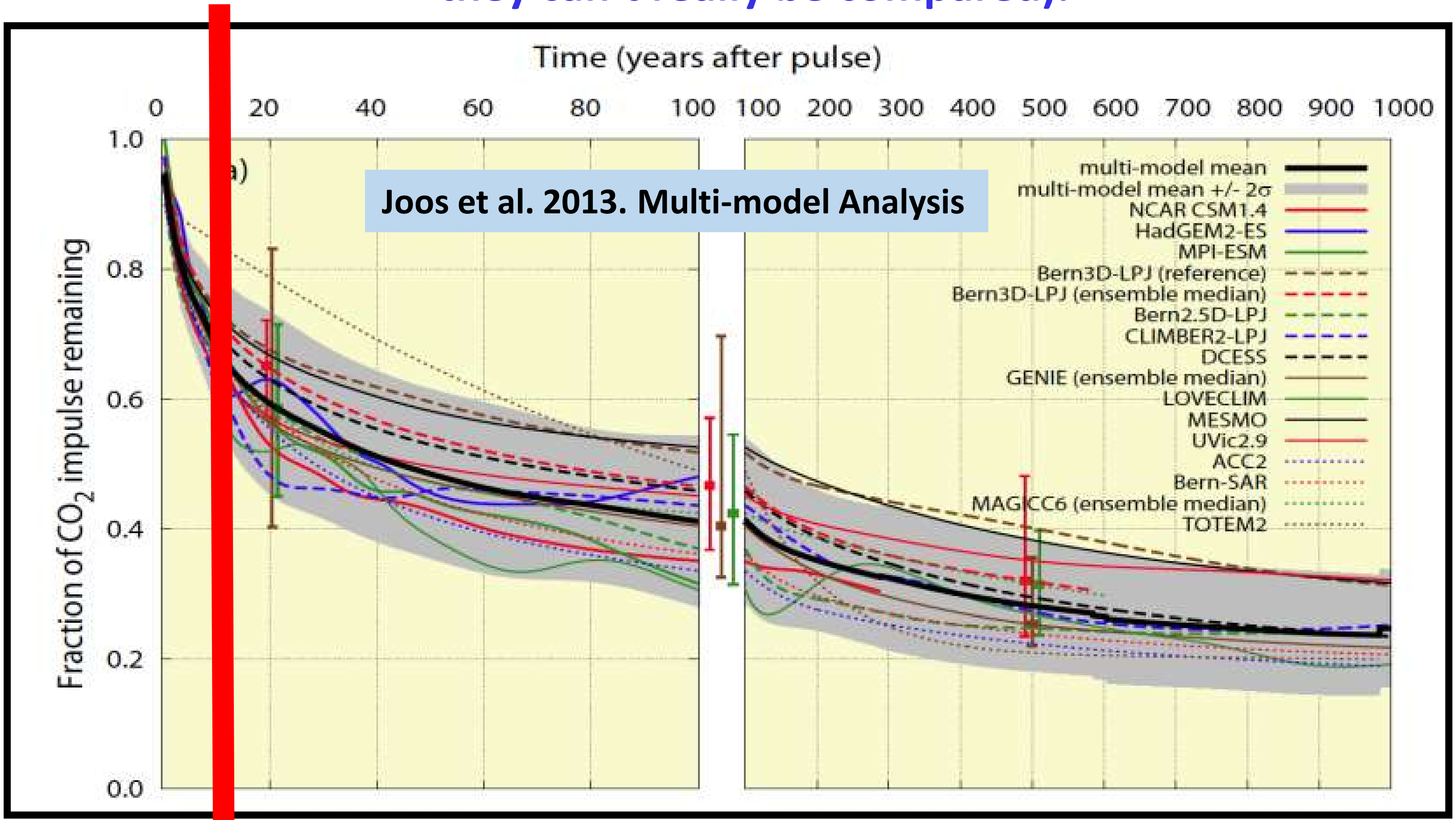
So how do we compare the impact of methane vs. carbon dioxide? The best approach is through radiative forcing calculations (though in truth, they can't really be compared).



12 year lifetime of methane

Methane is about 90 times more powerful, but only stays in the atmosphere for about 12 years. CO_2 is removed slowly over thousands of years. But, a key point is that with marsh restoration we can stop a long-term source of methane.

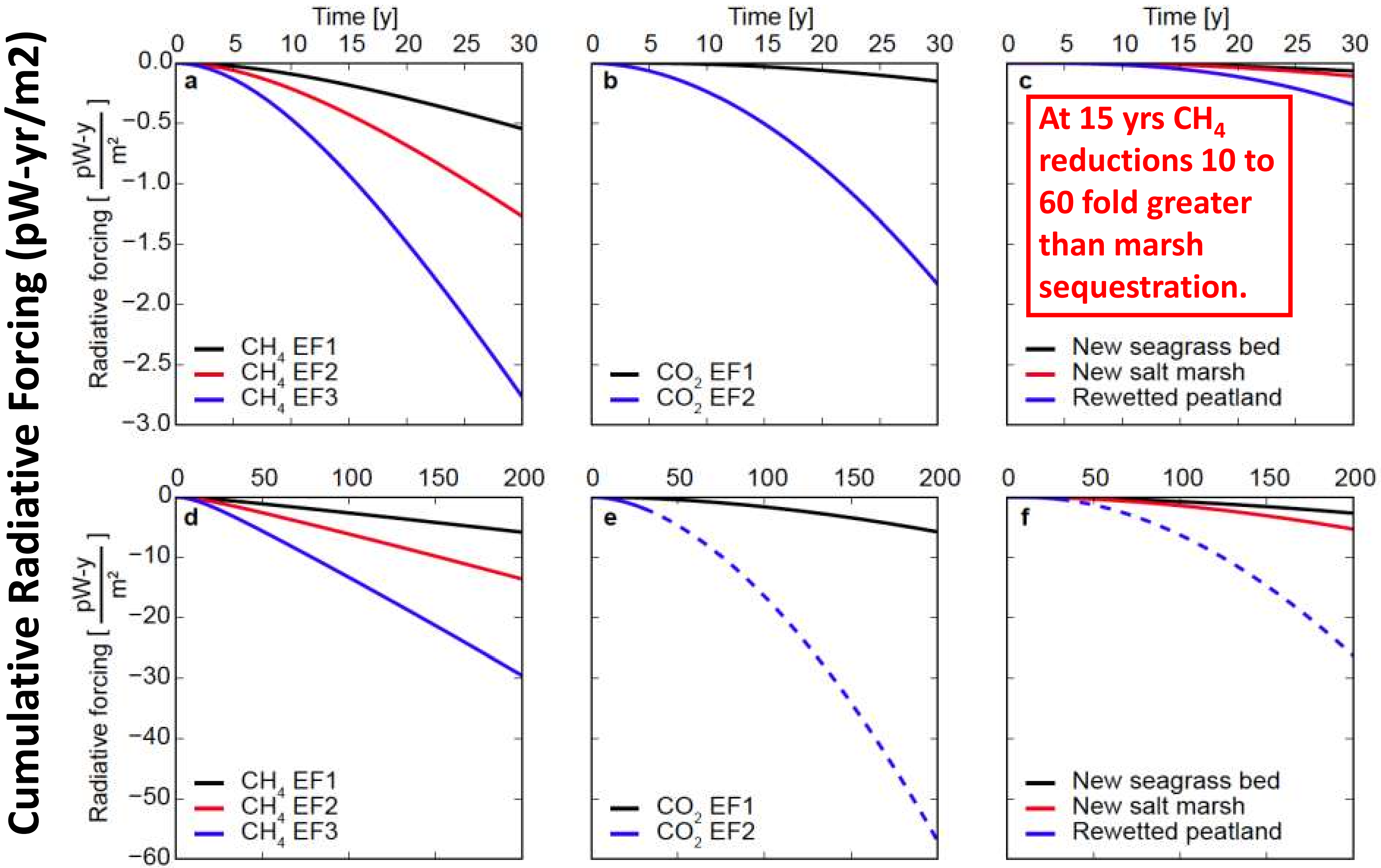
Restoration of Flooded/Freshened

Restoration of Drained

Other Wetland Carbon Management

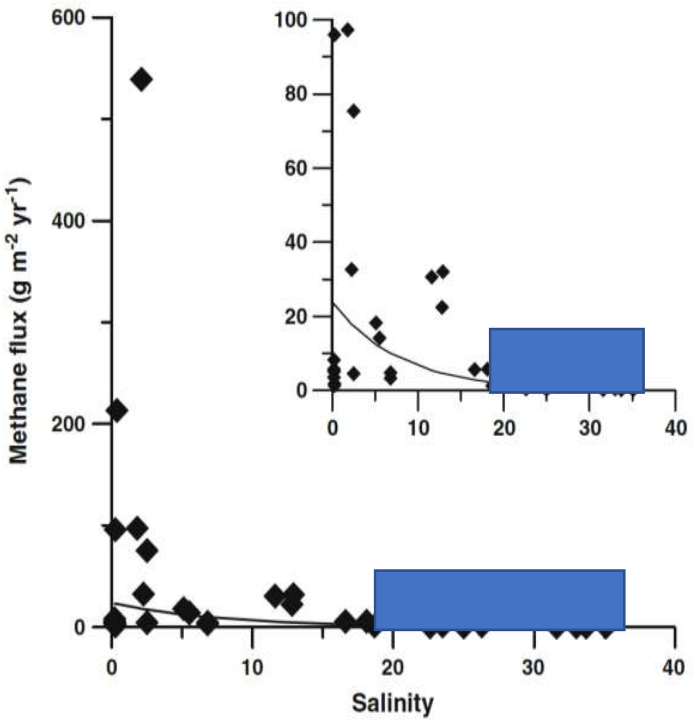
Kroeger et al. 2017

Years Post Restoration

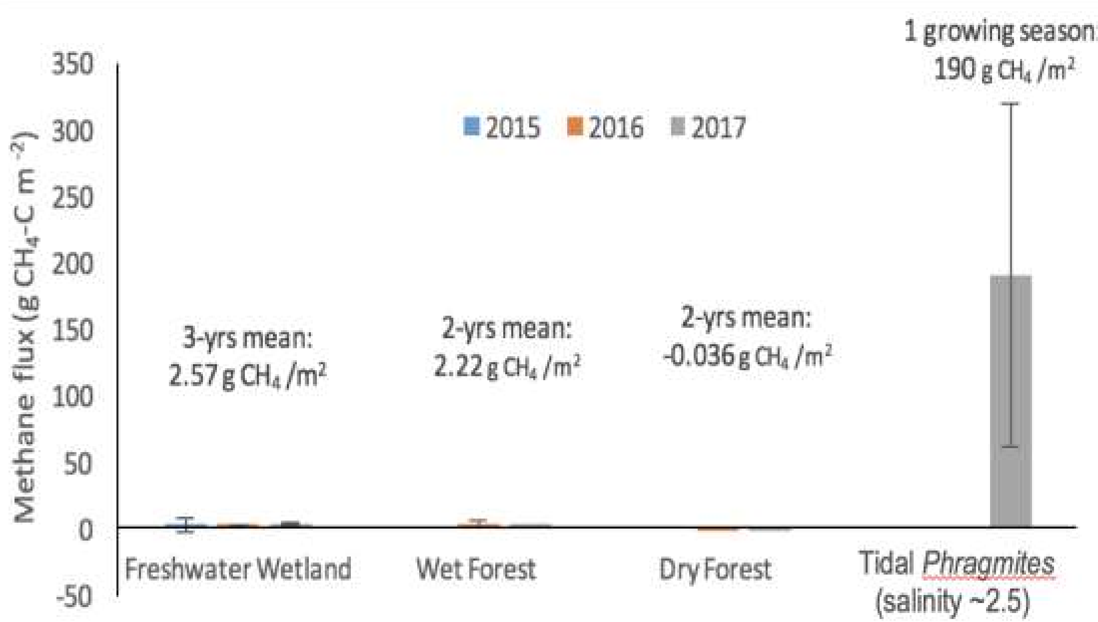


Research is still in progress, but results so far show that methane emissions within various settings in the Herring River do fall within the wide range reported for lower salinity wetlands: <u>The Phragmites wetland is a methane hotspot.</u>

Methane emissions as a function of salinity, across a broad range of settings (literature compiled by Poffenbarger et al. 2011)



Methane emissions in tidally-restricted, former salt marsh (F. Wang, et al. preliminary data).



Geography

Large impact per hectare, but how much area do they cover?

Features are difficult to quantify. Are spatially extensive, generally not mapped, and often no longer recognized as former salt marsh.

Examples:

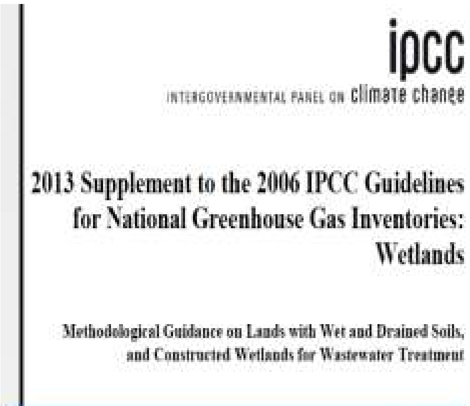
A. Herring River, NPS ~400 hectares

B. Woods Hole pond

C. Prime Hook NWR ~1600 hectares

Kroeger et al. 2017

Relevance to Inventories and C Markets



- **These are anthropogenic emissions**
- **Currently, there is no IPCC guidance for methane emissions in tidally-restricted wetlands, and the emissions are not currently quantified in any national Inventory.**
- **We are engaged in an effort to include emissions in the US Inventory. If other countries ultimately follow suit, then inclusion in the U.S. Inventory will promote widespread recognition and management**
- **There is potential to include the Herring River restoration within a voluntary C market, and this will be the first wetland methane reduction project credited**
- **Avoided anthropogenic emissions is an entirely distinct concept from biological carbon sequestration**
- **Future loss or degradation of the ecosystem cannot cancel past emissions reductions: As a climate intervention, does not suffer from non-permanence risk**
- **Climate impact is expected to be rapid, sustained, and have inherent permanence: Shorter project lifetimes can be considered**