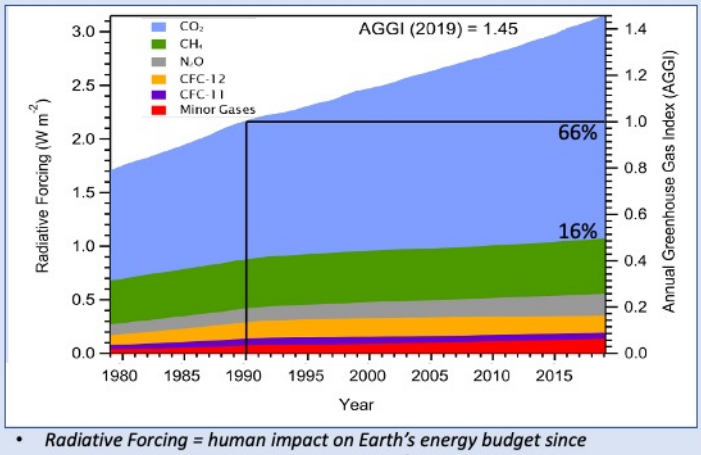
The Role Methane in the Earth's Energy Budget: Radiative Forcing



- *Radiative Forcing = human impact on Earth's energy budget since pre-industrial times. Units are Watts/meter^2. Based on NOAA network measurements.*
- *IPCC = Intergovernmental Panel on Climate Change*

www.esrl.noaa.gov/gmd/aggi

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Carbon Dioxide = CO_2 Methane = CH_4

The GWP-100 of CH_4 is 28-36, but there is less of it in the atmosphere.

The CO_2 contribution is rapidly increasing.

From Climate-Chemistry Models (IPCC):

ΔT (CO_2) = 0.75 (0.25 – 1.25) °C
ΔT (CH_4) = 0.5 (0.25 – 0.8) °C

1) GWP-100 is the global warming potential of CH4 (methane) over 100 years. On a per mass basis, CH4 is 28-36 times more powerful a greenhouse gas than CO2.

2) CO2 dominates radiative forcing and its growth over time.

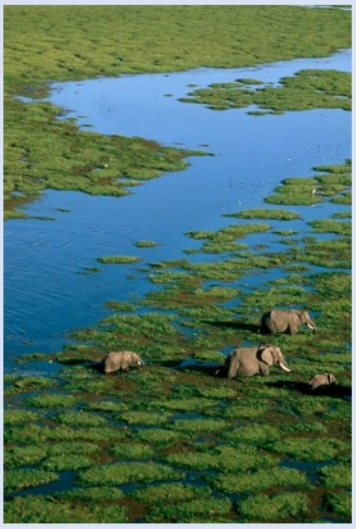
3) If we use climate-chemistry models to estimate how much CO2 and CH4 have contributed to observed changes in global average temperature (T) since pre-industrial times, we see that CH4 can have a large impact on T even though it's radiative forcing is relatively small. This is because it affects other radiative forcers that are also greenhouse gases through chemistry. Examples are ozone, WV in the middle atmosphere and aerosols.

4) There is a large spread in how the Intergovernmental Panel on Climate Change (IPCC) models attribute T changes to CO2 and CH4, indicating uncertainty. For CO2, the model spread is due to uncertainty in climate feedbacks with clouds, aerosols, the carbon cycle etc. For CH4, there is uncertainty due to atmospheric chemistry.

Methane - Climate Feedbacks

The amount of carbon in Arctic permafrost soils is ~4x what humans have already emitted.

Arctic CH_4 emissions could double over this century with accelerating increases next century.



Are tropical wetlands drying up or expanding?

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1) Examples of feedbacks between CH4 and climate – Arctic permafrost, tropical wetlands

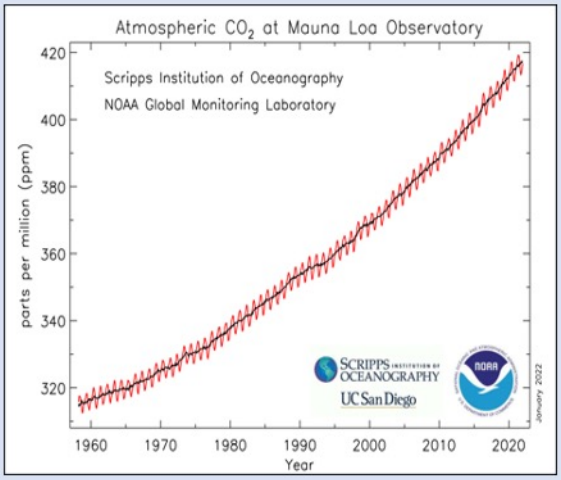
2) Some of the vast stores of carbon in Arctic permafrost soils will be mobilized to the atmosphere as CO2 and CH4

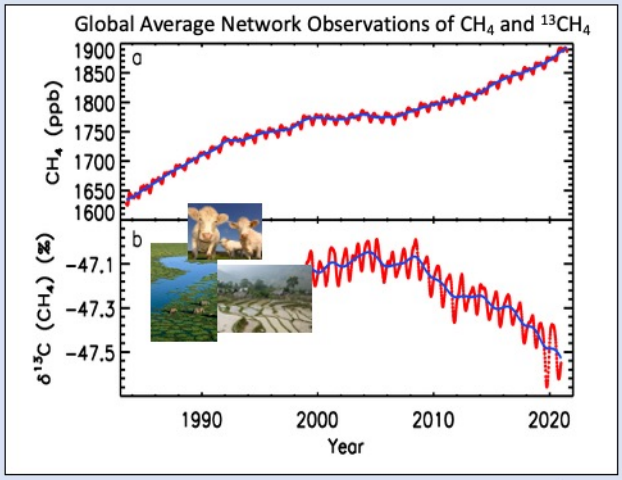
3) How much depends on how warm we let the Arctic get.

4) Changes in tropical wetlands could also result in changing CH4 emissions.

5) We need to understand these processes in order to improve our ability to make projections of future climate change, and craft policies that are consistent with climate goals.

Atmospheric Measurements of Carbon Dioxide and Methane





https://gml.noaa.gov/ccgg/

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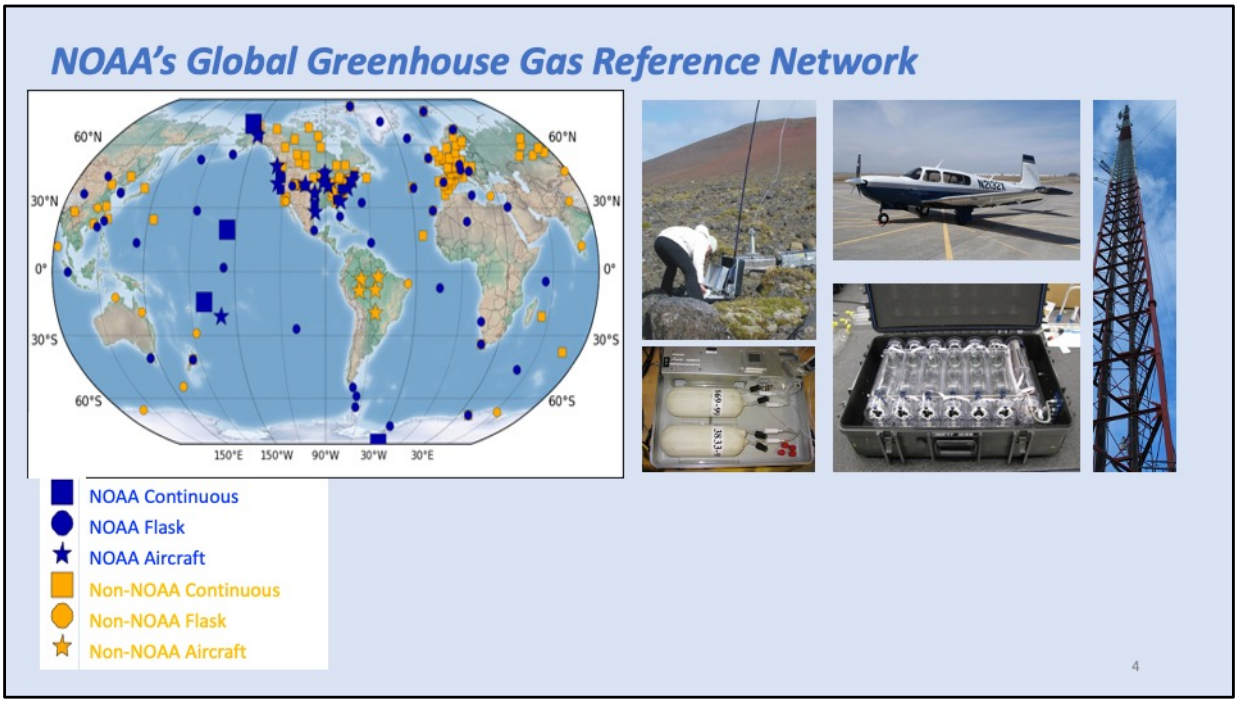
1) These are foundational measurements and they underly much of what we understand about atmospheric carbon since the mid-20th century.

2) CO2 is rising in the atmosphere due to fossil fuel emission and the concentration of CO2 is about 200x that of CH4

3) The growth of CH4 can be variable because there's chemical destruction in the atmosphere that is comparable to the source. We don't fully understanding what is driving the CH4 growth.

4) We measure other species that can help us to understand changes in CO2 and CH4 fluxes, such as ethane and 13CH4. The latter points to increases in microbial sources as the cause for the recent growth (bottom right grqaph). Microbes like to use the lighter carbon isotope for their metabolism. If the carbon in CH4 is getting lighter over time, then this implies that microbial sources are causing the increase.



1) Map shows NOAA network sites as well as sites operated by other networks.

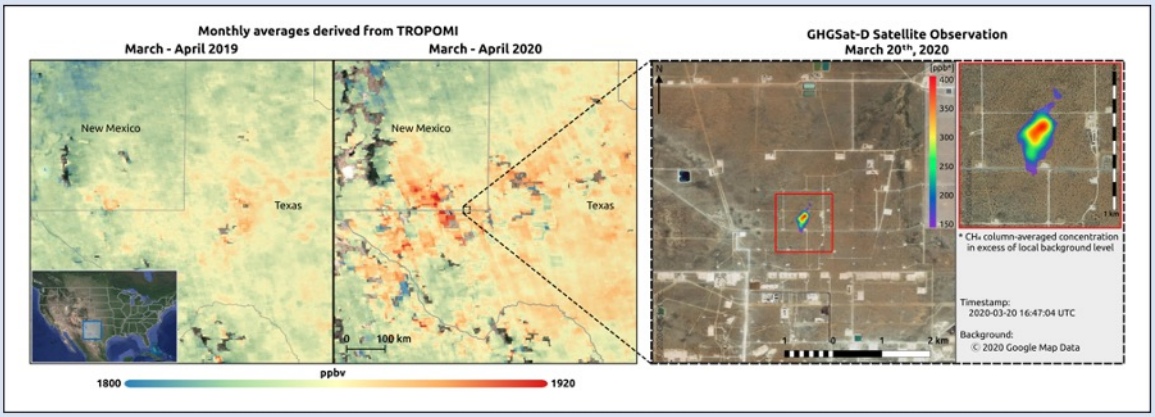
2) We have various ways to collect air samples – surface, aircraft, towers.. Aircraft and towers give us vertical profile information.

3) We measure many different gases, and some of these can tell us about the sources and sinks of CO_2 and CH_4 (like isotopes and co-emitted species such as CH4)

4) Data are carefully calibrated and collected over multiple decades.

Methane Observations From Space

High resolution space-based data can help us to identify strong-emitters.



But we need to know something about winds to get emissions from this data.

http://www.tropomi.eu/data-products/methane
https://www.ghgsat.com/en/

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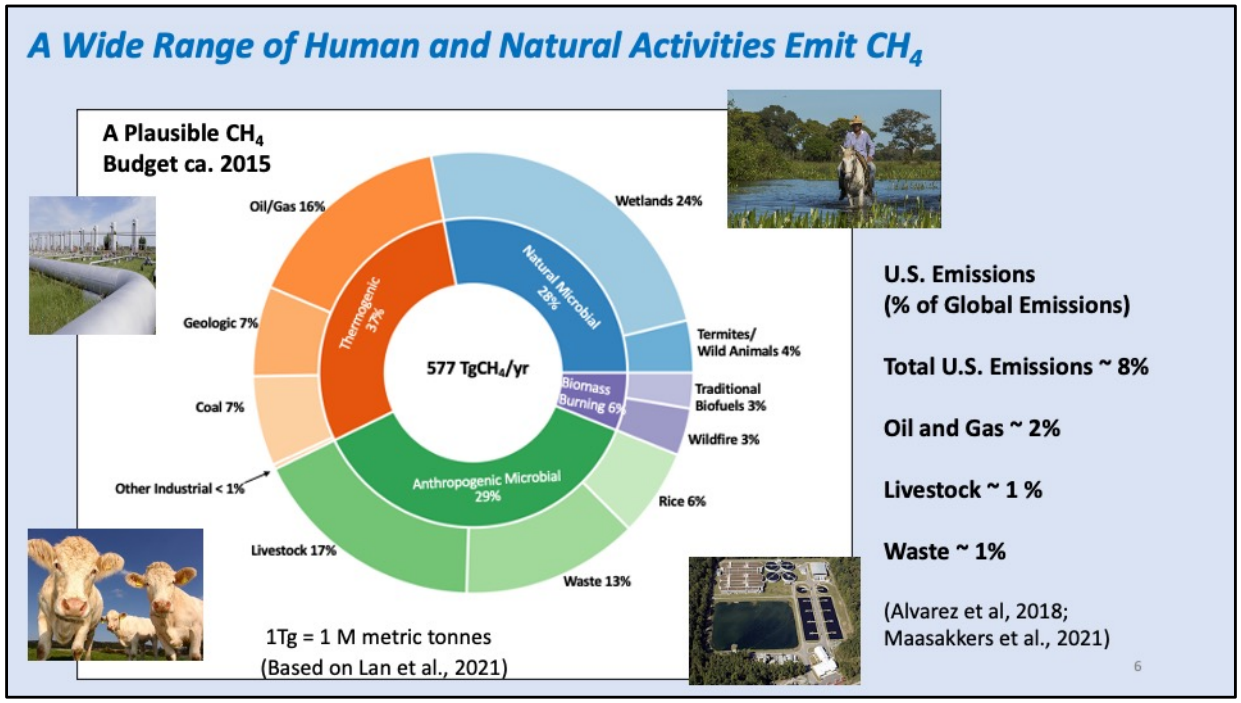
1) We can see emission hotspots from space, such as leaking O&G infrastructure shown here.

2) Some satellite instruments offer very high spatial resolution, allowing us to see leaks from individual facilities.

3) Satellites can only see the amount of CH4 averaged over the depth of the atmosphere; no vertical information.

4) To convert signals, like the apparent leak from oil/gas infrastructure shown on the right, we need to know something about winds.

5) More broadly, we use atmospheric models to convert observed concentrations to emissions. These global or regional models are similar to what we use for weather forecasting.



1) This methane emission budget is based on emission inventories (a bottom-up accounting of emissions based on economic data and production statistics) and atmospheric observations. The budget agrees with both CH4 and isotope observations.

2) The sunburst chart shows how global methane emissions are divided by source, the numbers on the right are the contribution to global emissions from the US according to published literature.

Extra Slides

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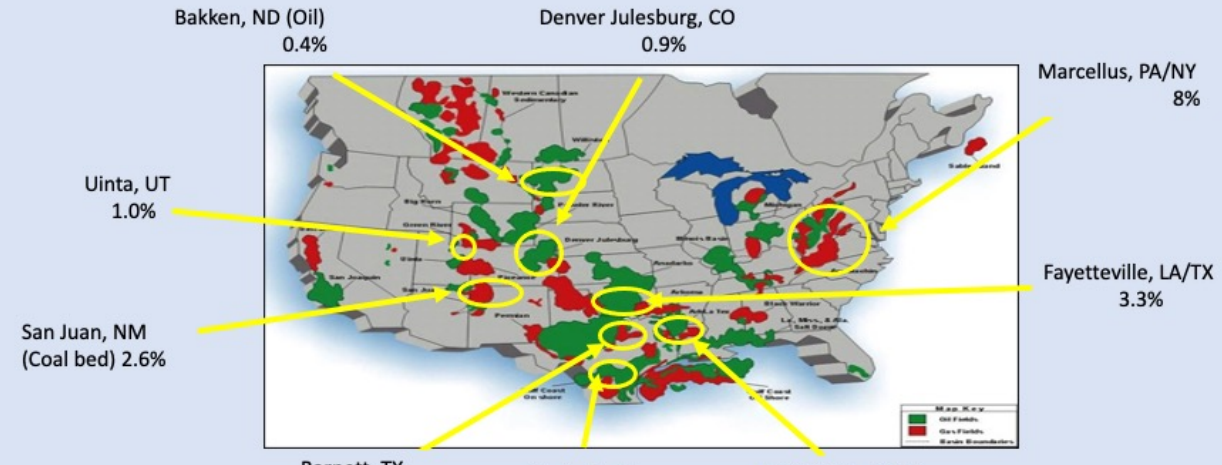
Research Frontiers: Reducing Uncertainty of Emissions



Peischl et al., 2016,2016
Karion et al., 2013,2015
Petron et al., 2012, 2014
Smith et al., 2017
Schwietzke et al., 2017

NOAA Aircraft Campaigns to Study Oil/Gas Emissions
Percent of Production Leaked to Atmosphere

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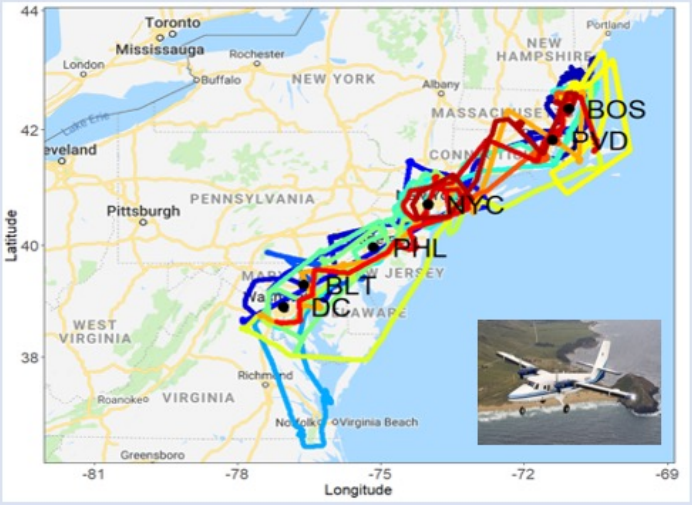
At NOAA we got interested CH4 emissions coming from oil and gas production during a study that we were doing in Utah in January of 2012 during a Ozone study that we were involved in. This study suggested that almost 9% of the gas being extracted was leaking to the atmosphere. Since that point we have been trying to understand whether what we saw in Utah was consistent throughout the country. As of last summer we have visited more than 9 different basins which account for more than 40% of the production of natural gas and 70% of shale gas production.

Research Frontiers: Reducing Uncertainty of Emissions

NOAA Aircraft Campaigns to Study Urban Emissions

Urban Natural Gas Emissions are 10x EPA Estimates

Total Methane Emissions are Likely to be 2x Higher



2018 East Coast Outflow Campaign

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Factor of 10 underestimate in NG emissions
Factor 2 underestimate in Total emissions
Inventories do not address leaks on the consumer side
Get rid of bar chart
Tie this into Stanford gas stove study