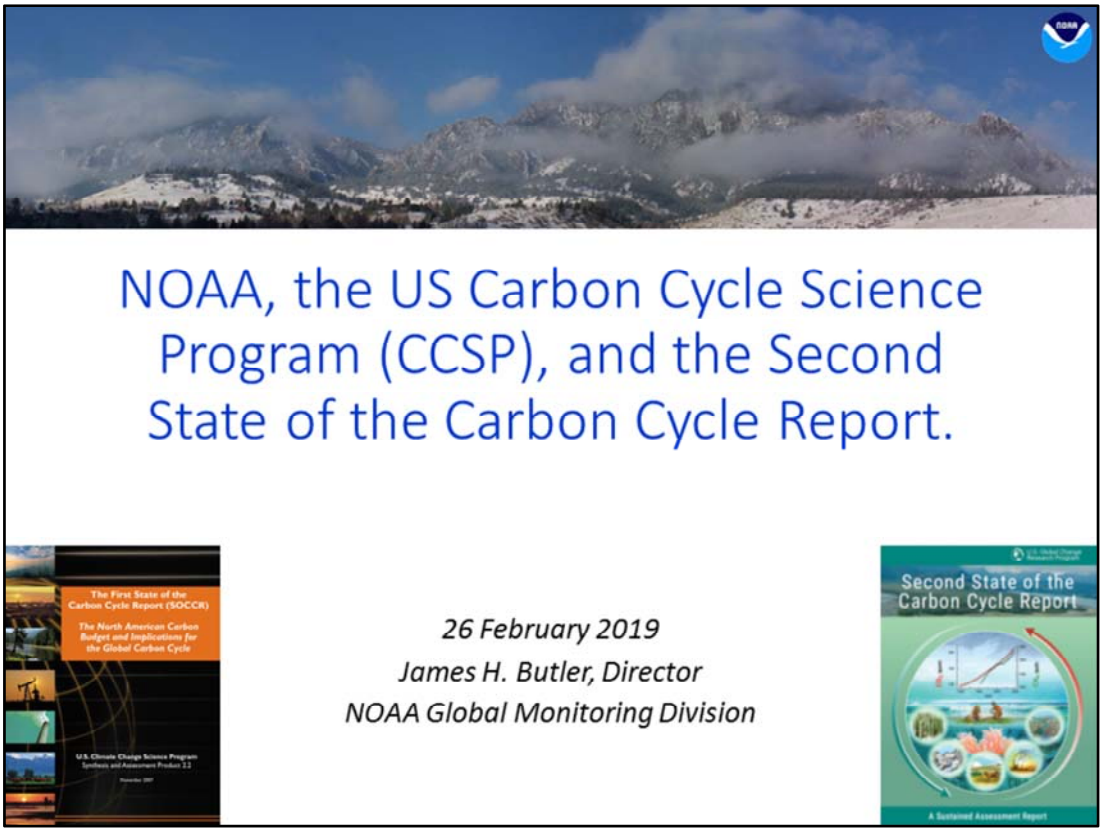
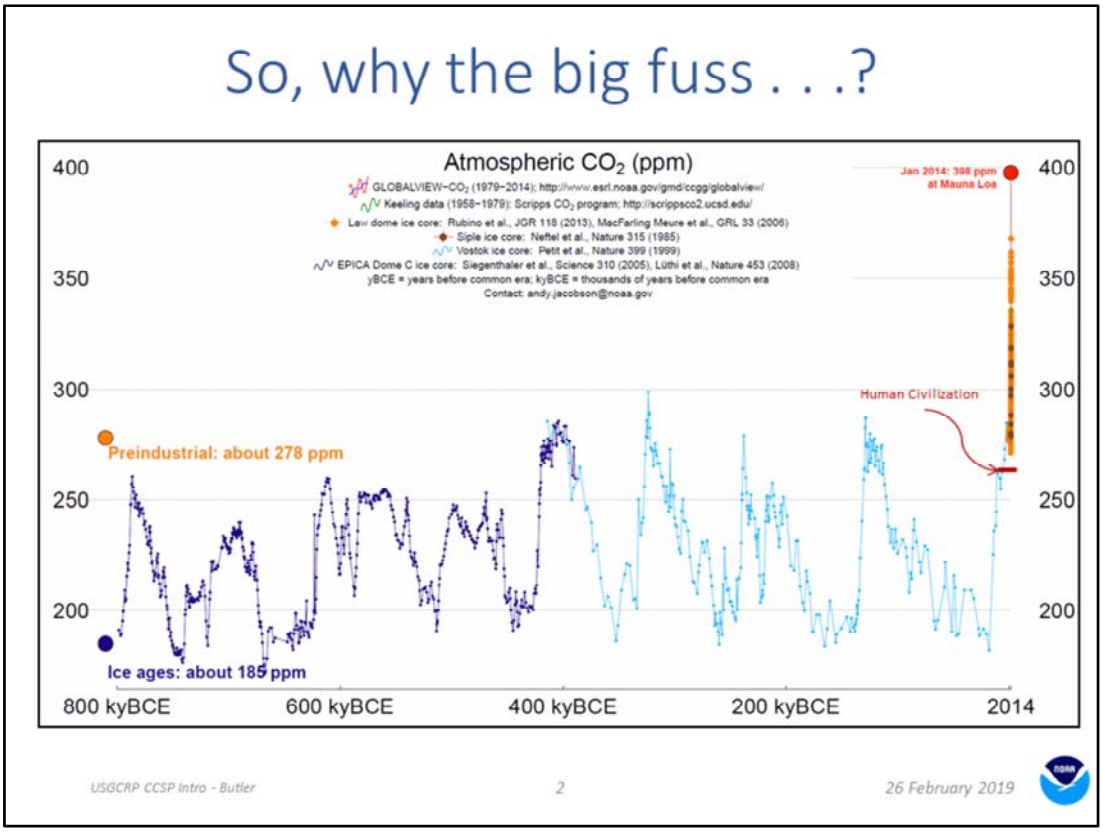
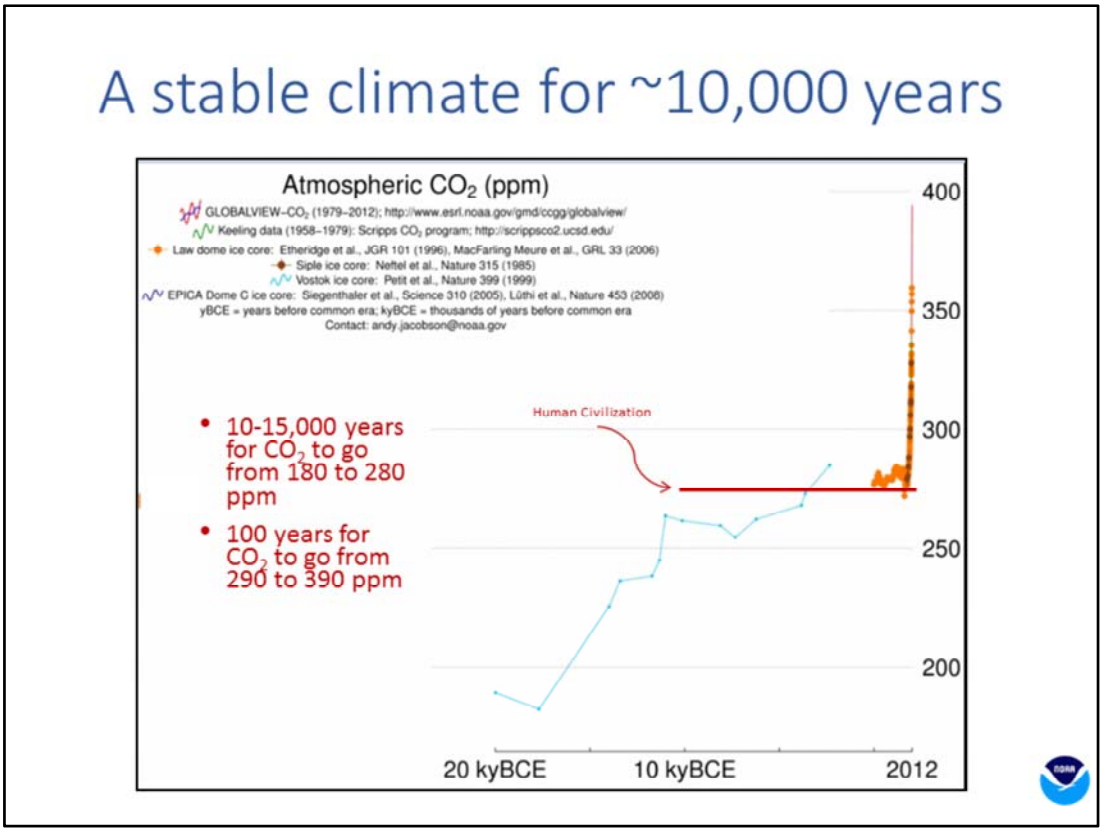


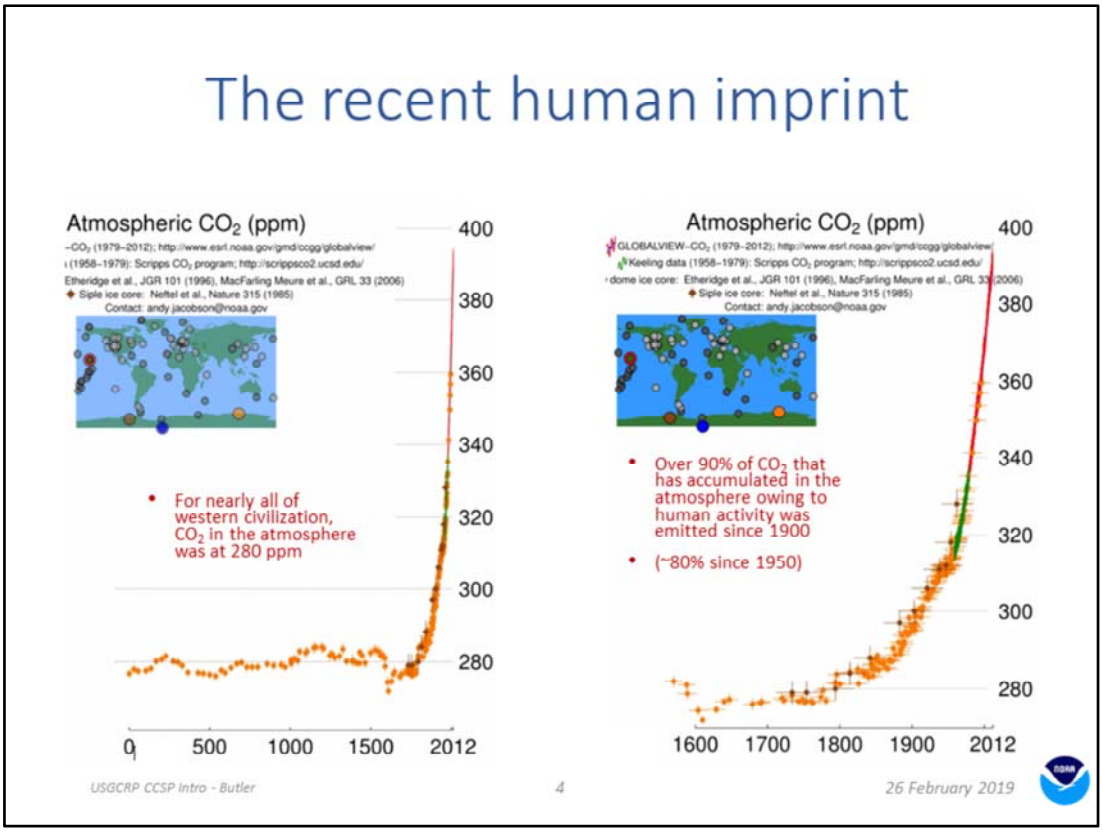
- I would like to give a brief overview of work of the Carbon Cycle Science program and NOAA's role in it.
  - I've been on the CCIWG almost 20 years now.
  - Ken Mooney and Kathy Tedesco go back even further than that.
- This is a multi-agency program, but NOAA's role in it is significant in many ways
  - NOAA is one of the dominant players in this effort
- SOCCR2 is our most recent product.
  - It is a major assessment of what we've learned over the past decade.
  - It is a tool for defining research needs and implementing solutions over the coming decade.



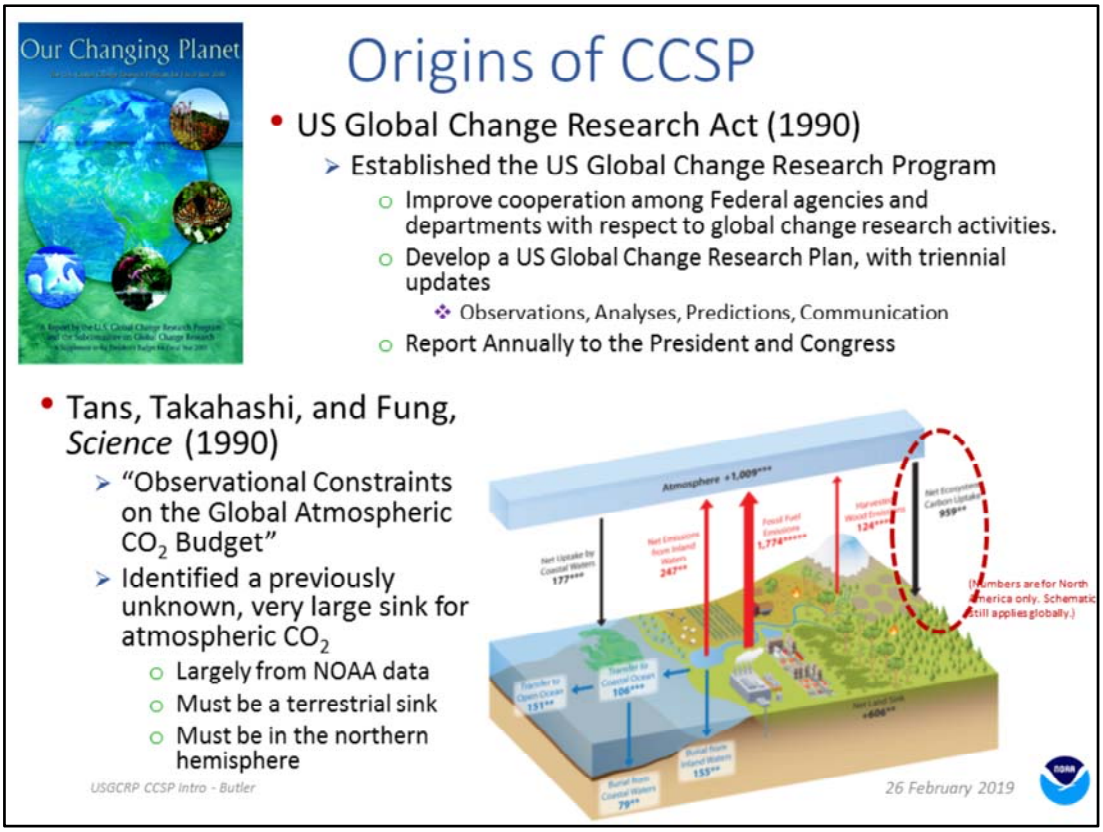
- You've all probably heard the following:
  - What's the big deal with CO2? It's oscillated in the past and so has climate. Why are we worried?
  - Besides, doesn't CO2 respond to temperature and not the other way around? Which is it?
- The answer is
  - Yes, CO2 has oscillated in the past with the ice ages, going roughly between 180 (ice age) and 280 (interglacial) ppm.
  - Yes, if temperature goes up, CO2 goes up, owing to increased respiration.
  - But the opposite is true, owing to the substantial warming effect of CO2 in the atmosphere.
    - The cycle does not change until acted upon from the "outside" – e.g., the sun, Earth's orbit, or CO2 emissions.
    - If there were no CO2 in the atmosphere, then Earth's temperature would be ~0° F (-18C).
- Note that Human Civilization has only existed during the last interglacial, a time when CO2 was settled between 260 and 280 ppm.
  - Agriculture was the driver of the evolution of civilization.
    - Hunting and gathering was a very inefficient way to make a living.
    - People had time to invent the wheel, build cities, write books, etc.



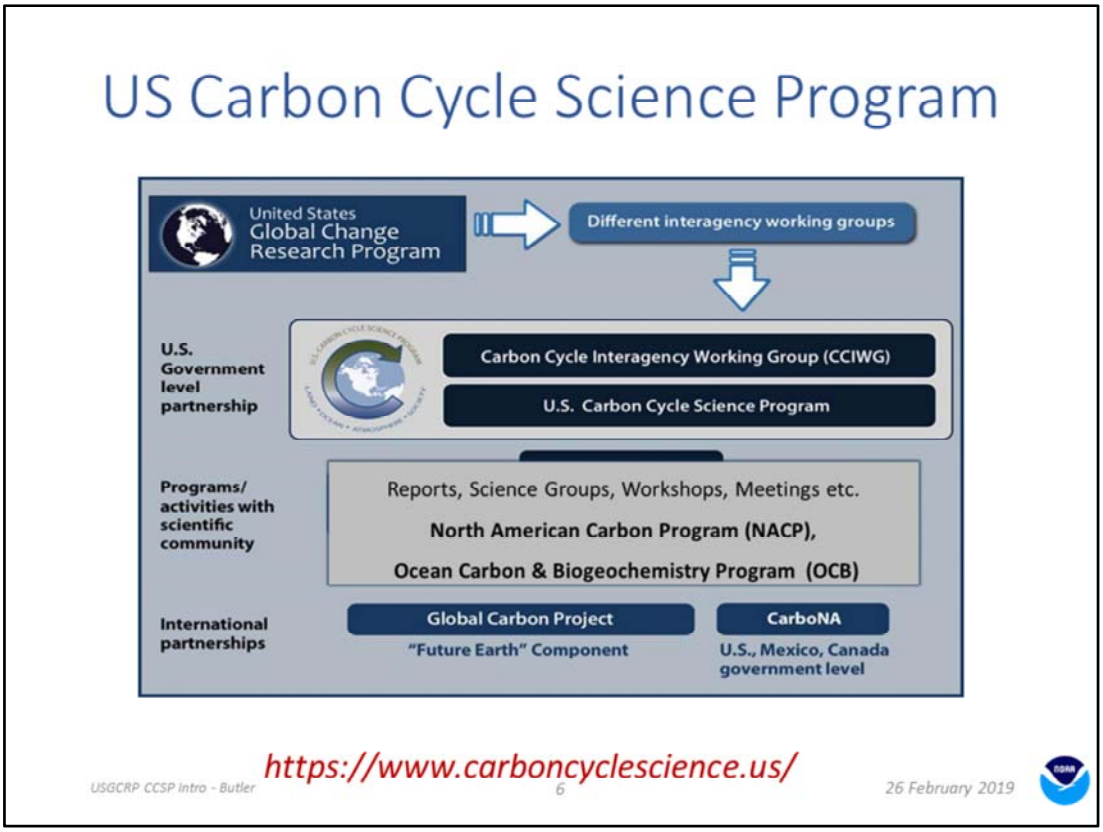
- Now, let's zoom in to the past 20,000 years.
  - During the last transition from glacial to interglacial, it took 10-15,000 years for CO2 to rise 100 ppm
  - Later, human emissions of CO2, mostly from fossil fuel burning, caused CO2 to rise 100 ppm in 100 years
    - 100 times faster than the last transition from glacial to interglacial.
- The world looked very different during the last glacial
  - E.g., glaciers up to a mile deep or more covered much of North America.
    - Ecosystems had time to adjust.
- What will the world look like when Earth system finally adjusts to this recent increase?
  - Will civilization be able to survive the transition, which will happen much faster than the last?
  - The species extinction rate on the planet is extremely high right now.
    - The Holocene extinction is 1000 times the background rate since 1900



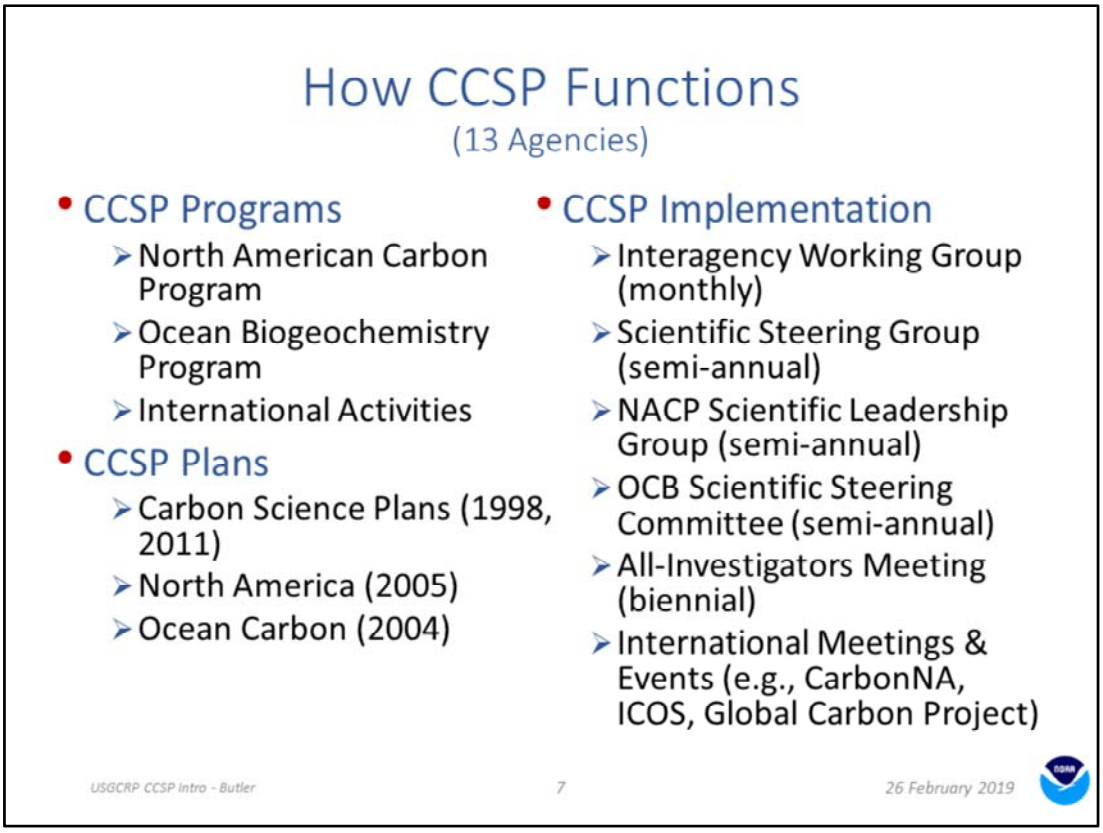
- Let's look closer . . .
  - Back ~2000 years and even before, all of Western Civilization progressed under a climate dictated by 280 ppm CO2 in the atmosphere.
    - Egyptians, Greeks, Romans, Ottomans, etc. drove civilization forward.
    - In Europe there were the Roman and Holy Roman Empires, the dark ages, the Reformation and Enlightenment.
    - And there were the Middle Warm Period and the Little Ice Age, which you can see in the CO2 record.
    - And then came the Industrial Revolution.
- Back 400 years (Reformation, Enlightenment, LaVosier, and Shakespeare)
  - We see evidence of the Little Ice Age .
  - We also see CO2 starting to rise around 1800.
    - It rose 10 ppm between 1800 and 1900,
    - And 100 ppm in the next decade.



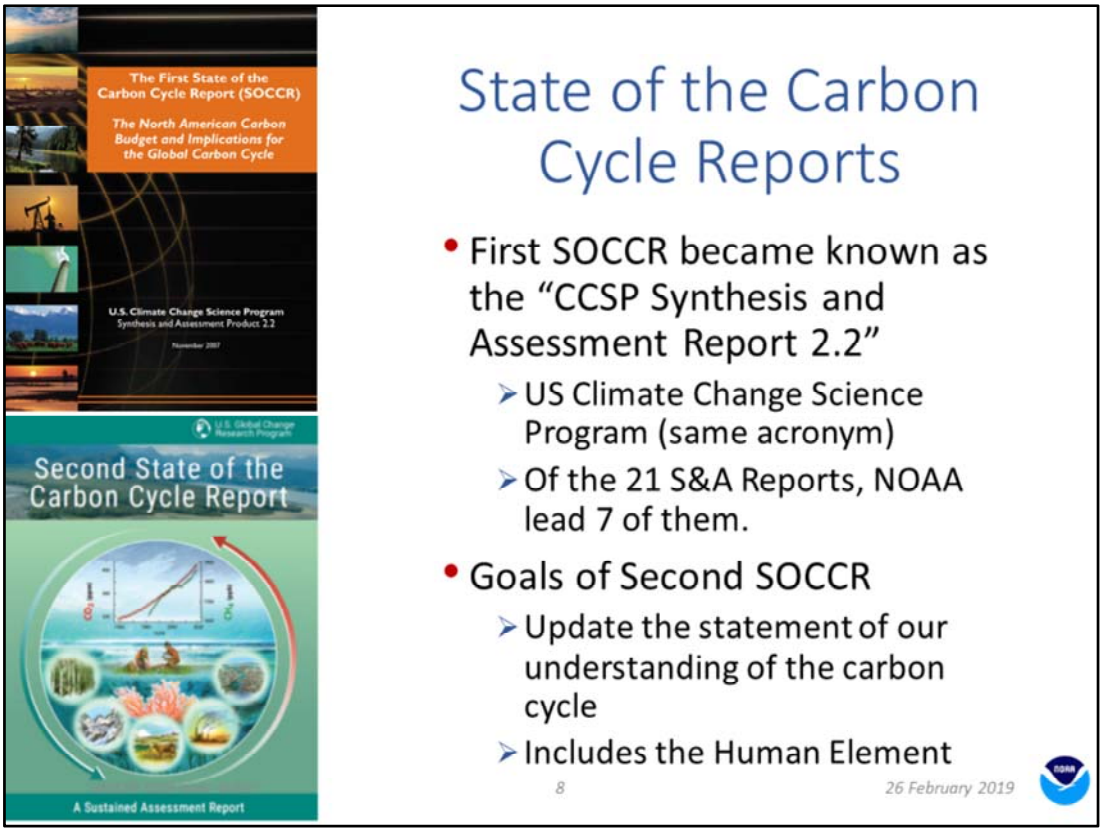
- So, what we are doing to this planet is unprecedented and scary.
  - It is an existential threat to civilization, especially because we know the CO2 we've already emitted into the atmosphere will remain for 1000s of years.
- Given this, the Global Change Research Act of 1990 required federal agencies to work together to observe, understand, assess, and predict change through research.
  - Report annually to the President and Congress.
- At the same time a paper in *Science Magazine* by Pieter Tans, Taro Takahashi, and Inez Fung made a discovery that revolutionized carbon cycle science
  - There was a large, missing sink in the CO2 budget
  - This sink had to be in the northern hemisphere
  - It was not an ocean source
    - . . . . Leaving terrestrial systems as the likely sink
    - Forests, grasslands, soils, etc.
- The implications of these findings were astounding



- So, when he USGCRP set up its plan, it established a number of interagency working groups.
  - One of them was the Carbon Cycle Working Interagency Working Group
  - Which governed the Carbon Cycle Science Program and quickly established two "sub programs within it.
    - North American Carbon Plan (NACP)
    - Ocean Carbon and Biogeochemistry Program (OCB)– (previously OCCP)

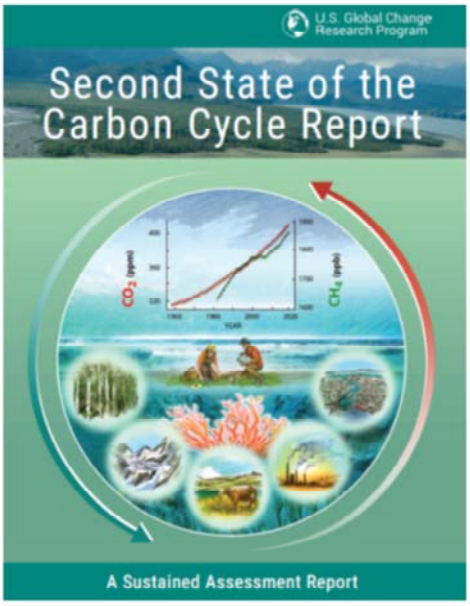


- The CCSP has met with considerable success for well over two decades, owing in good part to its organization and operation
  - Programs
  - Plans
  - Implementation



- Many publications have come out of this program as agencies increasingly coordinate funding.
  - Internally
  - Externally through grants
- But also through assessments.
  - The first SOCCR in 2007
  - Second SOCCR in 2018
    - Human element was highly emphasized in SOCCR2.

SOCCR2



- An update of how our understanding has improved since the first SOCCR report
- Four major sections
  - Synthesis
    - Overview and North American Carbon Budget
  - Human Dimensions
    - Agriculture, urban systems, energy use, tribal considerations
  - State of Air, Land, Water
    - Atmosphere, forests, soils, grasslands, arctic, wetlands, coasts, oceans
  - Consequences and Way Forward
    - Biogeochemical impacts
    - Science supporting decisions
- *https://www.globalchange.gov/content/about-soccr-2*

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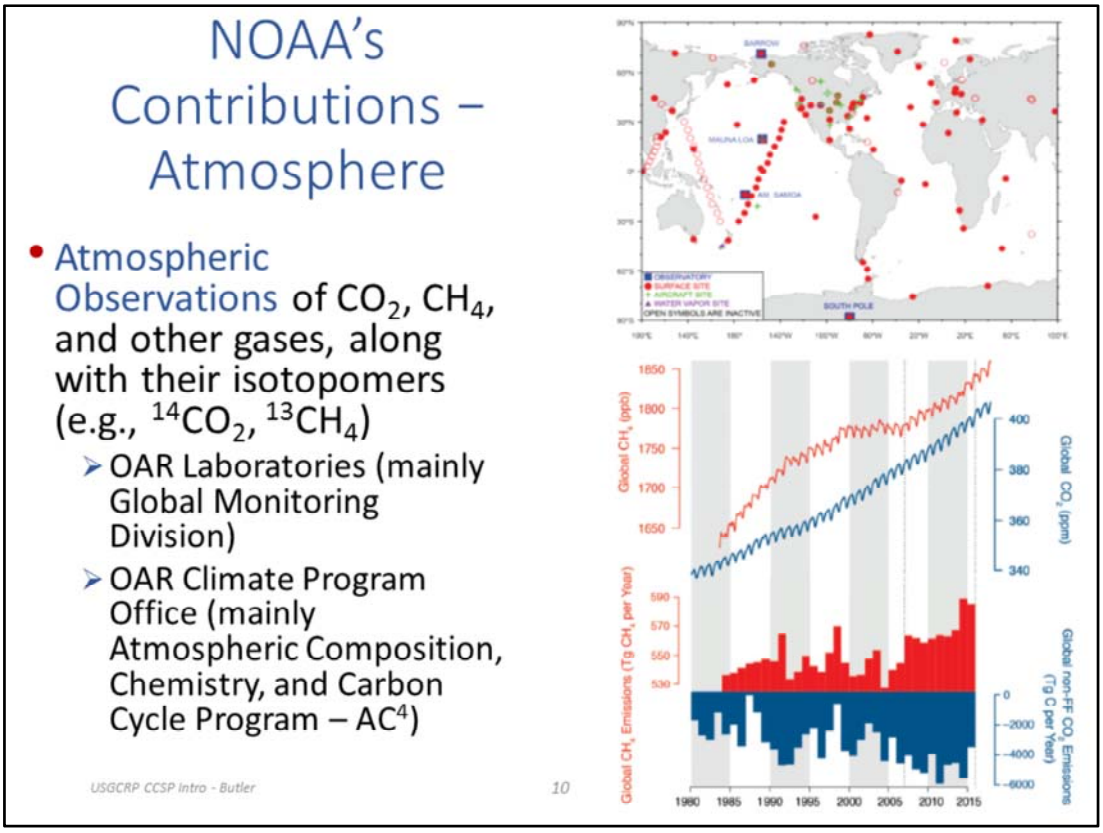
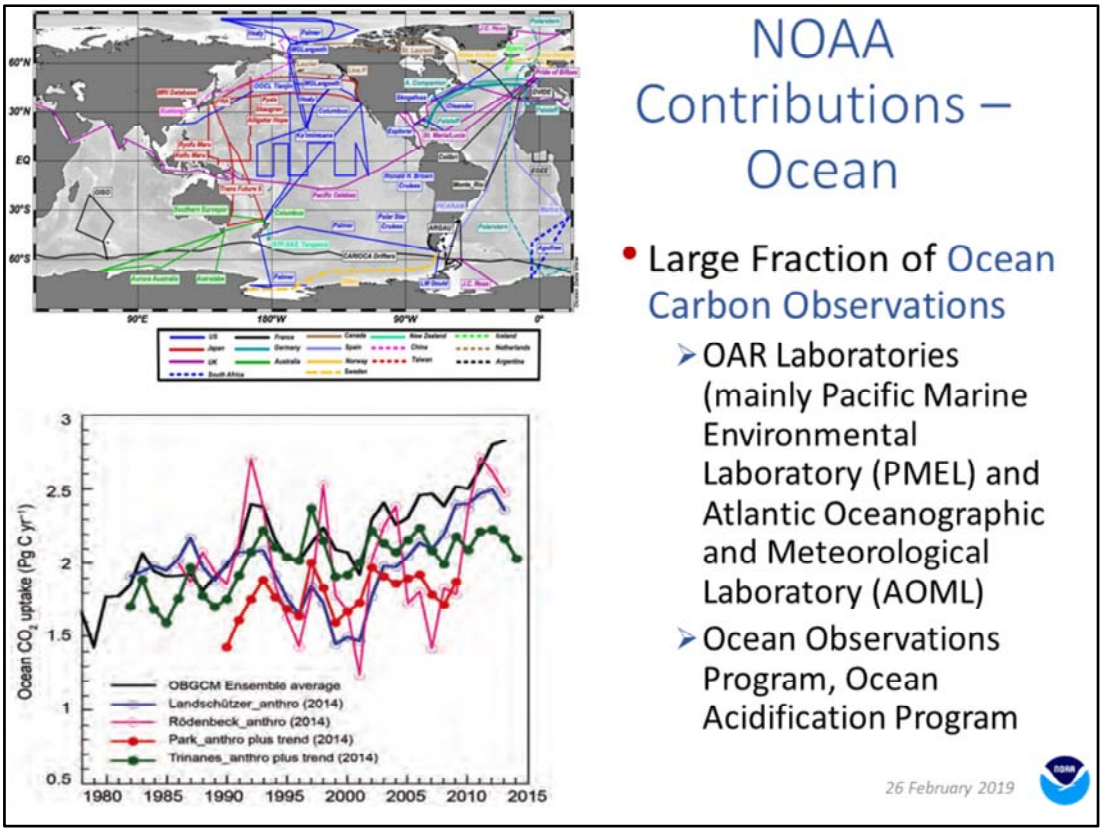
- Four major sections in the second report
  - The first SOCCR emphasized natural systems.
    - Sections on the state of the land, water, air
    - Energy, transportation, waste received some attention.
  - SOCCR2 deals with natural systems, but provides a greater assessment of human activities
    - Synthesis
    - Consequences and Way Forward
    - The Human Element
    - . . . In addition to the chapter on Air, Land, Water



- In the US, NOAA Global Monitoring Division has been responsible for nearly all measurements of carbon cycle gases in the atmosphere.
  - High quality, long term observations
  - The Climate Program Office has supported considerable process research as well.
- Top figure shows where long term observations are taken routinely.
- Bottom figure shows what we learn from atmospheric observations
  - You've likely seen these in various forms over the years.
  - Red is CH4, blue CO2, based on NOAA data.
  - Inversions of the trends and variability in CO2 and CH4 are used to invoke sources and sinks
    - E.g., subtract the increase in CO2 each year from the amount emitted to get natural sinks (blue bars)
    - For methane, similarly use its atmospheric lifetime and the observations to determine annual sources.
  - These put significant constraints on all terrestrial and ocean findings.



- Ocean measurements are more expensive and less frequent.
  - It's a long term, internationally coordinated effort
  - Blue lines in top figure are US observations
    - 1/2 of those are from NOAA measurements
- The plot below shows the increase of CO2 in the ocean based on several computational approaches.
  - They may differ in absolute amount, but the trends are pretty much the same.
  - CO2 in the ocean generally is keeping up with the atmosphere.
    - A good fraction of CO2 emitted each year is taken up by the ocean.

NOAA Contributions – AC^4 Collaborations

- CarbonTracker Lagrange (FY11 FFO)
- CarbonTracker (FY13 FFO) – 6 projects
- Urban Emissions (INFLUX, MEGACITIES Project, CO2USA Network) FY13, FY14, FY17 FFOs
- Methane emissions from oil & gas production (FY14 FFO)
- Methane sensor development (FY14 SBIR)
- National Academy of Science Methane Report (FY16)
- Satellite Data Assimilation (FY18 MAPP FFO) – 2 Projects
- ^{13}C Analysis
- AirCore - NESDIS interest for production of CO2 product

AirCore

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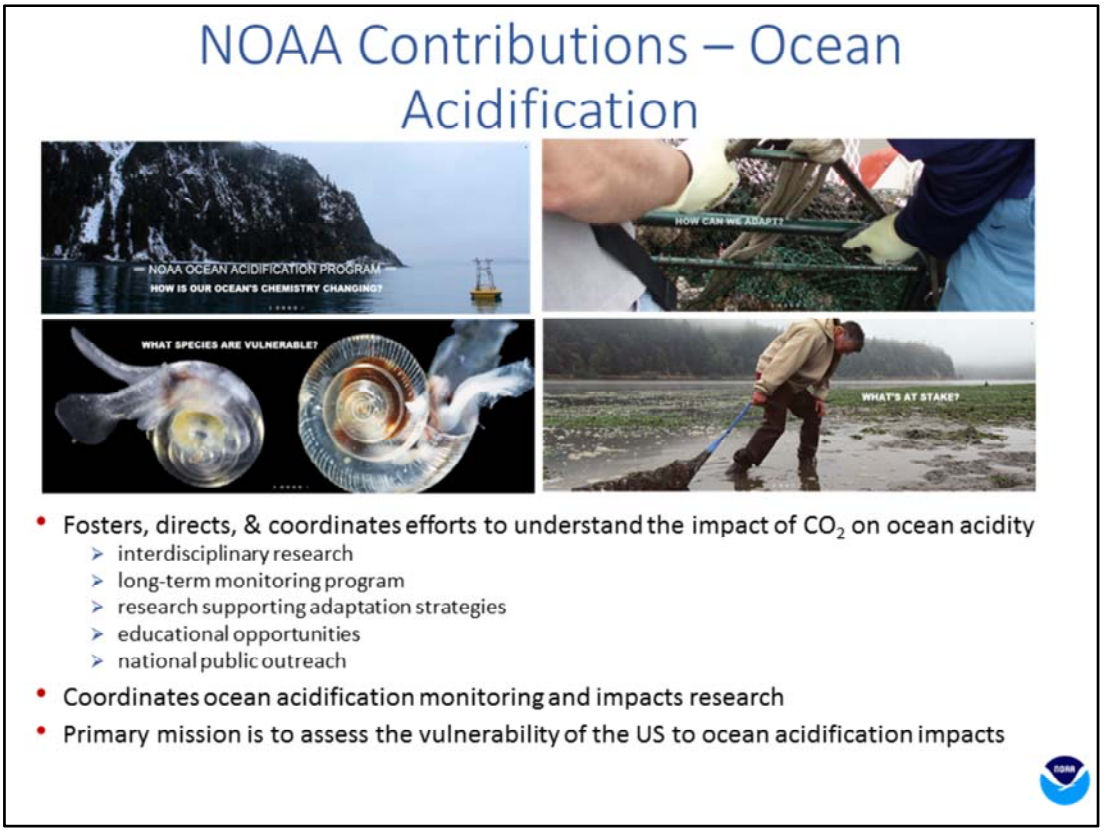
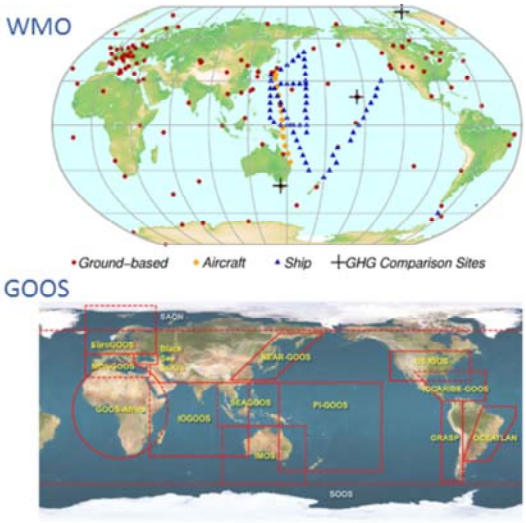
- The Climate Program Office's Atmospheric Composition, Chemistry, and Carbon Cycle Program (AC^4) has funded many projects to support our understanding of the carbon cycle.
  - Some of this is internal.
  - Some is external.
  - Often, but not always, funding is coordinated with other agencies where practical.
- These touch on several categories.
  - Understanding human and natural processes
  - Method development
  - Validation of satellite retrievals
  - Assessments (e.g., Nat'l Acad Sci)



- Acidification of the ocean by increasing CO2 in the atmosphere is unquestionable
  - There is only one way to stop ocean acidification
    - Stop emitting CO2 into the atmosphere.
  - Maybe there are ways to understand and deal with it
    - Thus the need for research
- The Ocean Acidification Program conducts numerous activities to understand the impact of CO2 on ocean acidity
  - Monitoring
  - Research
  - Coordination among agencies and internationally
  - Education
  - Outreach

NOAA Contributions – International Engagement

- Global Carbon Project
- WMO Global Atmosphere Watch
- Global Ocean Observing System
- Global Climate Observing System
- Integrated Carbon Observation System
- In-service Airborne Global Observing System
- Numerous Bilaterals



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- I could probably show a dozen slides on NOAA's international engagements to understand the carbon cycle.
  - There are many and they are varied in nature
  - These include
    - Bilateral agreements to fill flasks or operate instruments in remote areas
    - Participation on ships from different programs in different nations
    - Participation in numerous international programs and their committees (acronym soup)
      - E.g., GOOS, IOOS, GAW, GCOS, AOPC, OOPC, GEO-Carbon, Global Carbon Project, ICOS, IAGOS, etc.
    - Collaboration in analysis and modeling
  - The international activities shown on this slide are only a few.

Contact Information, etc.

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GMD Website: www.esrl.noaa.gov/gmd
"Pumphandle" Movie Link (3.5 min):
https://www.esrl.noaa.gov/gmd/ccgg/trends/history.html

- I don't know if this is the time for questions, but if time is available, we can do some now.
  - Or we can deal with questions after the next presentation.
  - I do note that if you found the first few slides interesting, they are taken from a brief movie developed by Andy Jacobson of NOAA's Global Monitoring Division.
    - The movie runs 3.5 min, but you pause anywhere to think about it.
- So now let me introduce the next speaker.

Next Speaker – Gyami Shrestha

- Director, U.S. Carbon Science Program (since 2011)
  - Co-led the development of SOCCR2, serving as lead editor, lead author & contributor
  - Directs the U.S. Carbon Cycle Science Program Office and Carbon Cycle Interagency Working Group (CCIWG)
- Previous Experience: research, management & consulting
  - Proposal Review Panel – King Abdullah City for Science & Technology (2010-2011)
  - NAS Science and Technology Policy Fellow (2009) – America's Climate Choices 'Advancing the Science of Climate Change' 2010 Report.
  - Center for Rural Technology (2001-2003) – Decision-support tool development, Nepal & South Asia
- Education
  - Ph.D. – Environmental Systems, University of California Merced (2011)
  - M.S. – Soil Sciences and Water Resources, University of Wyoming
  - B.Sc. (Honors) – Environmental Sciences, Kathmandu University
  - Executive Management/Leadership Certificates – Georgetown Graduate School

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- Dr. Shrestha hails from Nepal.
- Her academic career has focused on Earth's environmental systems,
  - . . . completing her PhD at University of California, Merced.
  - She has experience in soil sciences, water, and ecosystems research.
  - She understands how to work the interface between science and society and is skilled in management and leadership.
- Most importantly, with these skills and capabilities, she has overseen the US Carbon Cycle Science Program as its Director since 2011.
  - Given that this represents 13 agencies, ~200 scientists, and all their quirks, that is not a trivial task.
  - I have thoroughly enjoyed working with Gyami these past years and find her dedication, perseverance, and overall commitment to the mission to be inspiring and invigorating.