DOE ARM
Engage with Strategic Partners

Gannet Hallar and Tim Onasch

Outline

- 20 minutes – introductory presentation
  - Engage with strategic partners
- 30 minutes – 2 evenly split groups conduct brainstorm activities
  - *List of strategic opportunities:*
  - *List of problematic roadblocks:*
- 30 minutes – prioritizing activities
  - *Prioritized list of actionable items:*
- 10 minutes – summary and reflections

Summary

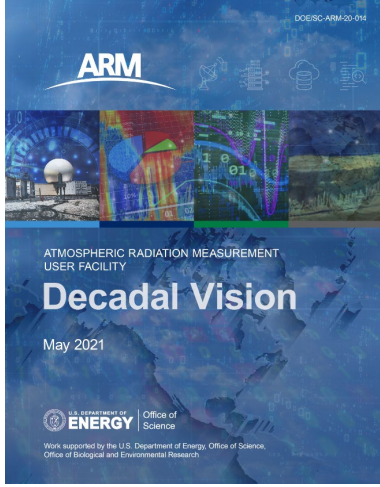
- The DOE ARM program was established following several international studies based on the conclusion that cloud–radiative feedback is the single most important effect determining the magnitude of possible climatic responses to human activity
- ARM's current focus is on providing infrastructure for climate-relevant observations, analysis, and modeling
- ARM has created a unique network of supersites developed to inform models scaled from atmospheric column, to geographical region, to global
- Looking ahead, we believe that ARM can greatly benefit by actively ***engaging with strategic partners***

Formation of DOE ARM

- "The ***U.S. Department of Energy (DOE)*** was already concerned about the potential impact of the increasing content of CO_2 in the atmosphere on future climate in the early 1970s (see Riches 1983) and commissioned a set of six state-of-the-art reports (e.g., MacCracken and Luther 1985) that attempted to highlight the uncertainties in general circulation models (GCMs) and their underlying parameterizations ***well ahead of the Intergovernmental Panel on Climate Change (IPCC) program***."
- "To obtain a better understanding of the GCM conundrum, the DOE instituted several intercomparison studies"
    1. "an ***intercomparison of longwave radiation codes*** (wavelengths . 4 microns) was initiated by Fred Luther in 1982"
    2. "a ***GCM intercomparison project***, was begun by Robert Cess and Gerald Potter in 1984"
- "These projects eventually grew to ***major international intercomparison studies*** that led the DOE to the conclusion that cloud–radiative feedback is the single most important effect determining the magnitude of possible climatic responses to human activity."
- "This conclusion, in turn, led to the ***establishment of the Atmospheric Radiation Measurements (ARM) Program***"

Ellingson, R.G., Cess, R.D., and Potter, G.L. (2016). The Atmospheric Radiation Measurement Program: Prelude. *Meteorological Monographs* 57:1.1-1.9. doi:10.1175/AMSMONOGRAPHS-D-15-0029.1.

2020 ARM Decadal Vision



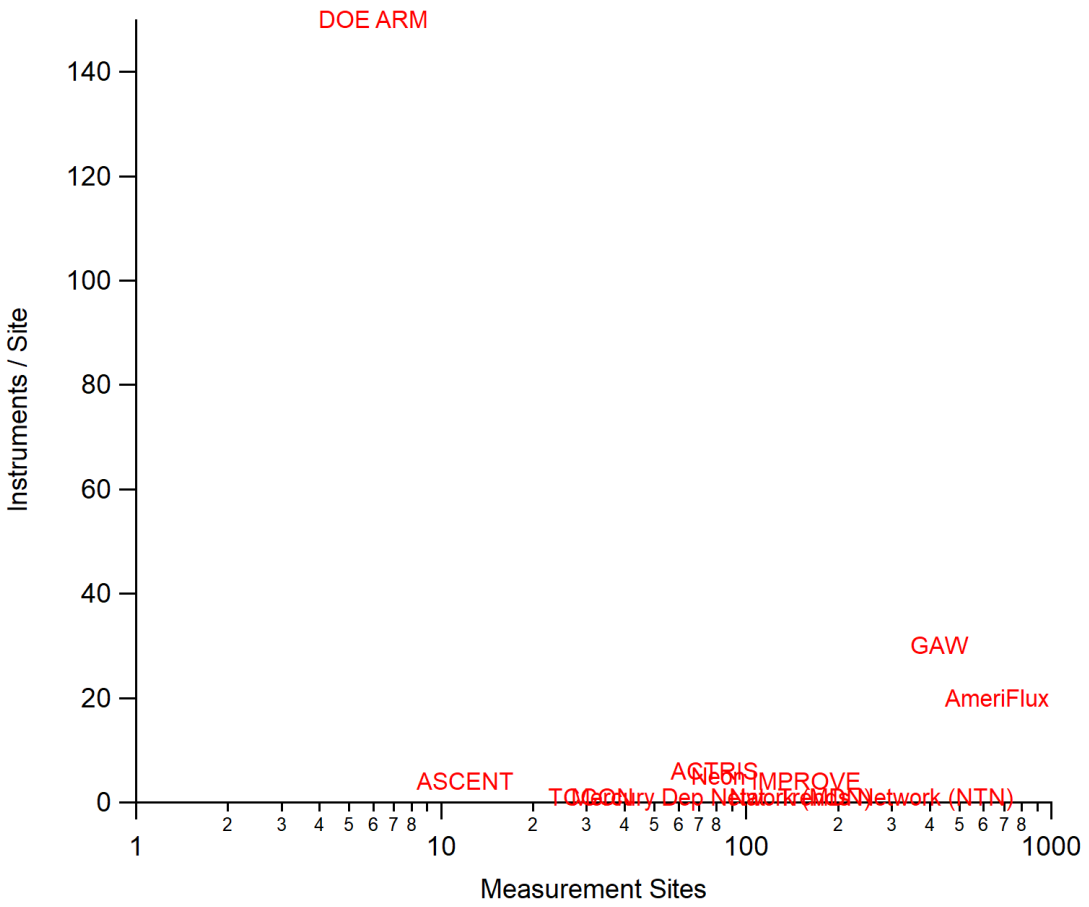
The updated vision for ARM is:

To provide the research community with the best array of field observations and supporting state-of-the-art data analytics to significantly improve the representation of challenging atmospheric processes in earth system models.

The updated ARM Vision will be sustained by activities organized within four themes:

1. Provide comprehensive and impactful field measurements to support scientific advancement of atmospheric process understanding.
2. Achieve the maximum scientific impact of ARM measurements through increased engagement with observational data by ARM staff, including the application of advanced data analytical techniques.
3. Enable advanced data analytics and community use of complex ARM data sets through the advancement of computing infrastructure and data analysis.
4. Accelerate and amplify the impact of ARM measurements on earth system models by exploiting ARM and ESM frameworks to facilitate the application of ARM data to ESM development.

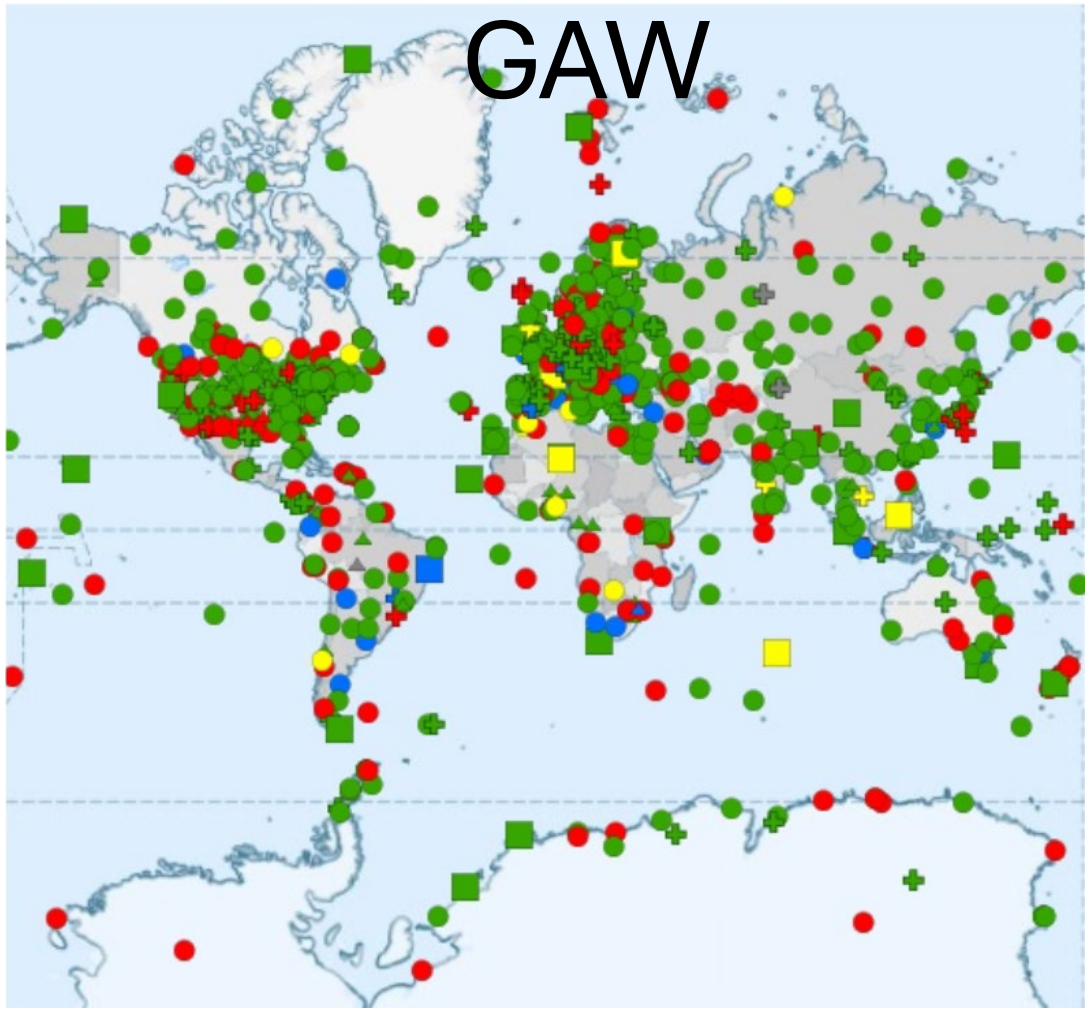
DOE ARM is unique as a network



- DOE ARM supports several different measurement “sites” (including fixed and mobile, airborne, and shipborne)
- DOE ARM stands out in the sheer number of instruments per site, but also in the limited number of sites

NOTE: Not meant to be exhaustive, nor especially accurate for any given network, but the trend is readily apparent

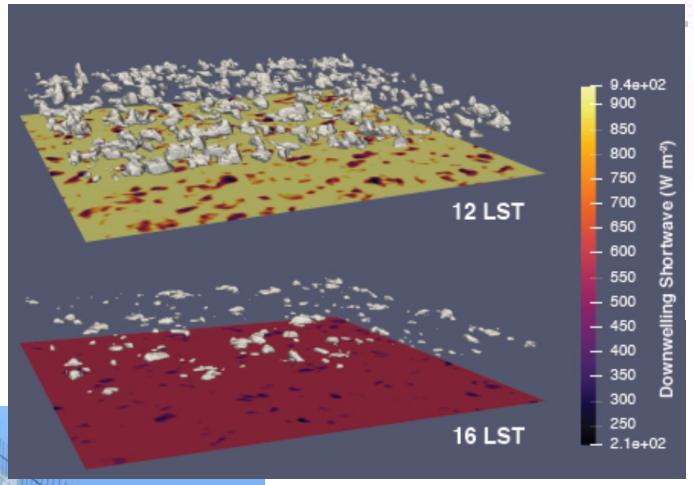
ARM is a unique network

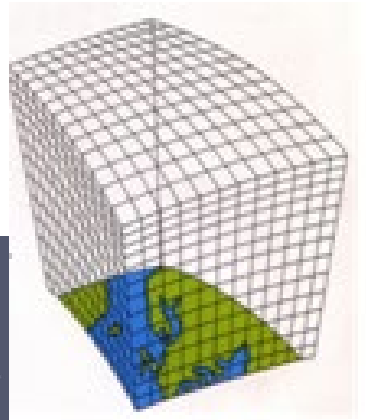


- ARM operates Fixed and Mobile Sites

ARM is unique as a super site

- Southern Great Plains (SGP) observatory consists of in situ and remote-sensing instrument clusters arrayed across approximately 9,000 square miles (23,310 square kilometers) in north-central Oklahoma and southern Kansas





GCM

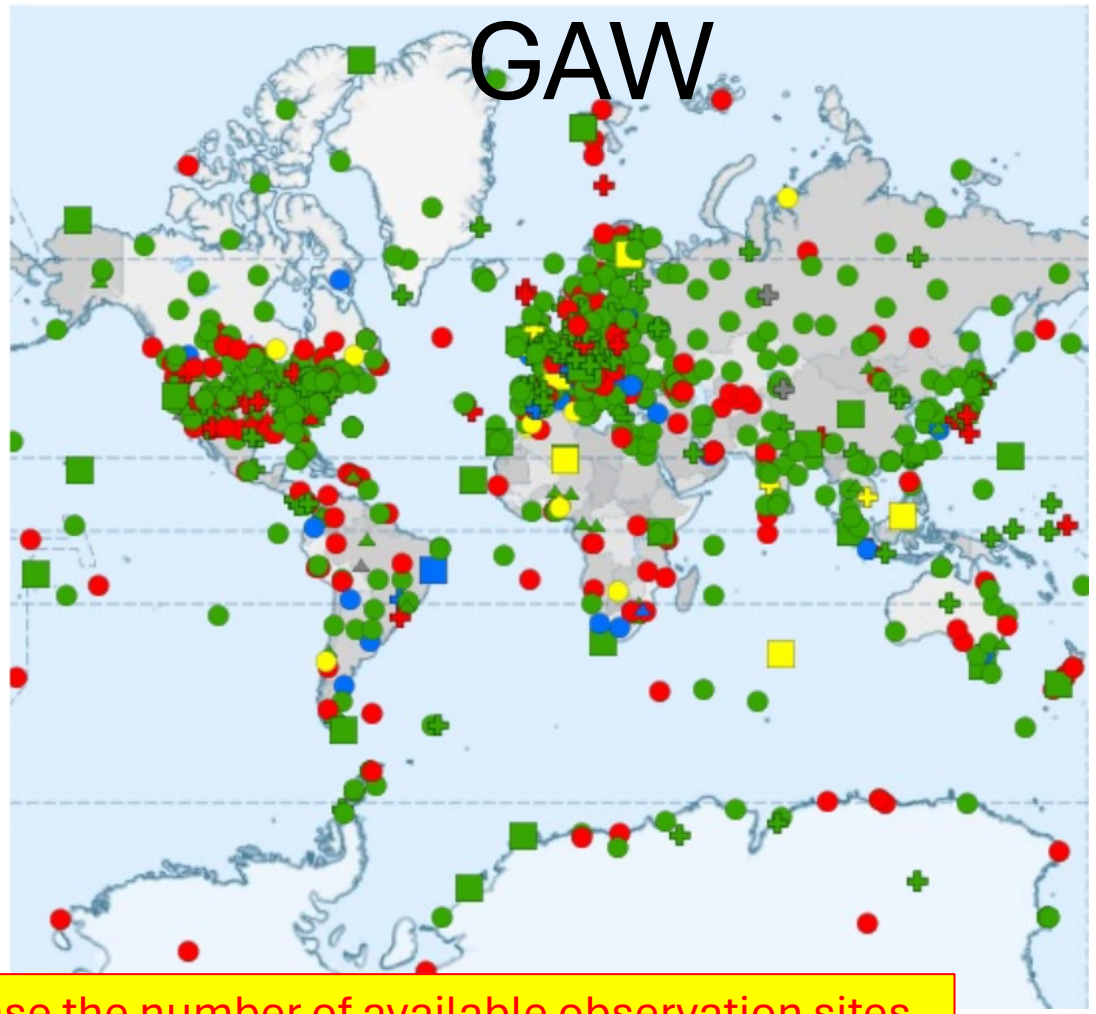
- LASSO uses large-eddy simulation (LES) modeling combined with observations to enable researchers to more easily use ARM's suite of observations
- Goal of bridging the gap between observations and scales within large forecast and climate models

So, what is missing?

- High number and spatial variability of measurement sites
  - Regional observations (and assessments) are becoming more important
  - Open Ocean sites
  - Urban vs Rural – environmental impact
- Aerosol and Trace Gas measurements
  - DOE ARM does not deploy a complete suite for aerosol or trace gas measurements
  - Vertical and spatial profiles
  - Organic compounds – VOC's, IVOC's, LVOC's, ELVOC's
- Measurements of detailed aerosol-related processes
  - IOP's at ARM sites
- Uniform protocols for data
  - Collection
  - Calibrations and uncertainties
- Direct partnerships with other entities
  - AmeriFlux network (centralized under DOE)
  - FAN, IMPROVE, and ASCENT (national networks)
  - ACTRIS and GAW (international networks)
  - AERCOM and CHIMP (modeling efforts/communities)

- Note the resemblance to the breakout sessions – we believe that direct partnerships can help address some or all of these missing elements

Missing – high number of sites



- ARM could partner with multiple networks to increase the number of available observation sites

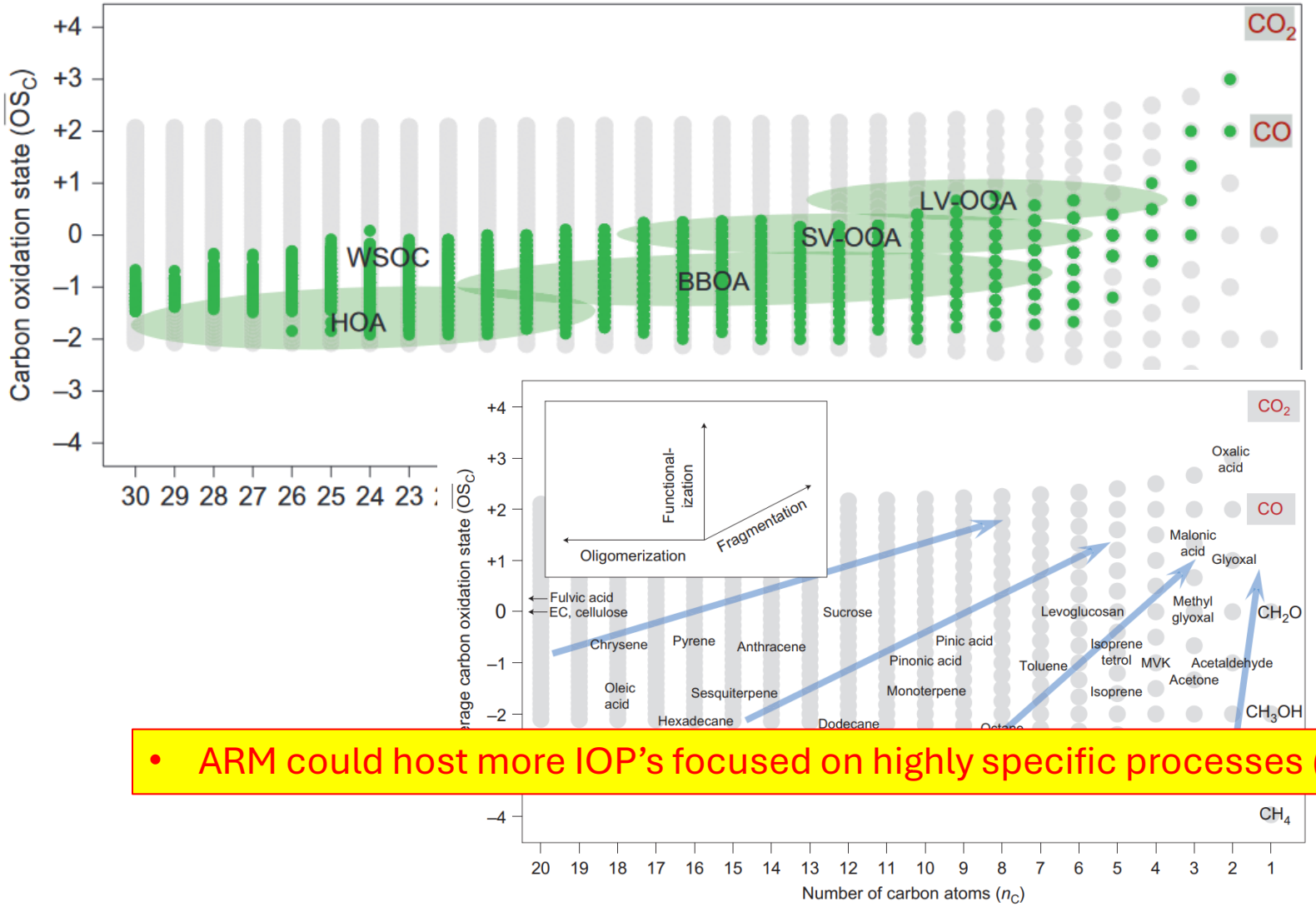
Missing - spatial variability in network sites

- “There is high confidence that regional reanalyses better represent the frequencies of extremes and variability in precipitation, surface air temperature and surface wind than global reanalyses and provide estimates that are more consistent with independent observations than dynamical downscaling approaches. {1.5.2, 10.2.1.2, Annex I}”

- ARM could partner with multiple networks to increase the variability of available observation sites

Intergovernmental Panel On Climate Change (Ipcc) (2023). Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st ed. Cambridge University Press.

Missing - Organic (and inorganic) Compounds



- In gas and particulate phases
- Influence CO_2, methane, and O_3 budgets and radiative forcing

- ARM could host more IOP's focused on highly specific processes (e.g., CCN, IN, Vertical profiles)

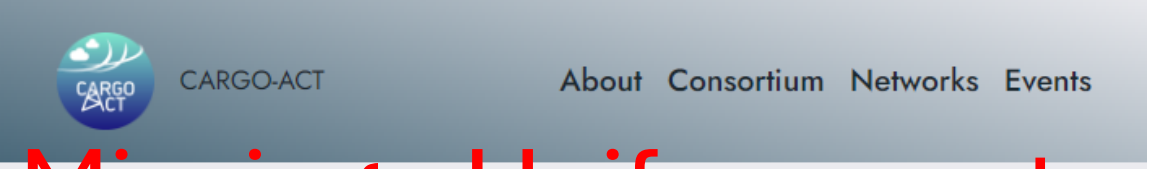
Kroll, J.H., Donahue, N.M., Jimenez, J.L., Kessler, S.H., Canagaratna, M.R., Wilson, K.R., Altieri, K.E., Mazzoleni, L.R., Wozniak, A.S., Bluhm, H., Mysak, E.R., Smith, J.D., Kolb, C.E., and Worsnop, D.R. (2011). Carbon oxidation state as a metric for describing the chemistry of atmospheric organic aerosol. *Nature Chem* 3 (2):133–139. doi:10.1038/nchem.948.

IOPs – idea at ground sites

- ARM implementing negative of idea – focused on calibration procedures and time frames – AOP – very good, but not everything

- Still worth pursuing positive idea – once we have the procedures and time frames – then run IOPs – which collate small projects at ASR/ARM and allows ARM to open these up to other funding sources/fundings – hence a multiplier!
  - Tie into modeling (i.e., LASSO project)
  - PI's bring science focus and more complex aerosol-related instrumentation

- ARM mobile facilities best represent this type of approach, but why limit to mobile facilities?



Missing - Uniform protocols for data – Example #1

Networks

Research infrastructures and observation networks in CARGO-ACT

ACTRiS
Exploring the Atmosphere

Research Infrastructure for Aerosols, Clouds and trace gases

ACTRIS (https://www.actris.eu) is a long-term activity with more than 100 European partners within a single, pan-European, sustainable and distributed research infrastructure, to cover both the 4-dimensional (4-D) observations (latitude, longitude, height, time) and process understanding for short-lived atmospheric constituents: aerosol, cloud and trace gases. The ACTRIS mission is to integrate, harmonise and distribute the high-quality observations provided by first-class facilities for atmospheric research currently located in 22 European countries and other locations globally, and to operate the pan-European distributed research infrastructure providing open and effective access to unique resources and services to a wide user community of Earth system research. ACTRIS was established as an ERIC in 2023 and is represented in this consortium by FMI, NILU, UHEL, BIRA-ISAB, CNR, CNRS, TROPOS and INOE.

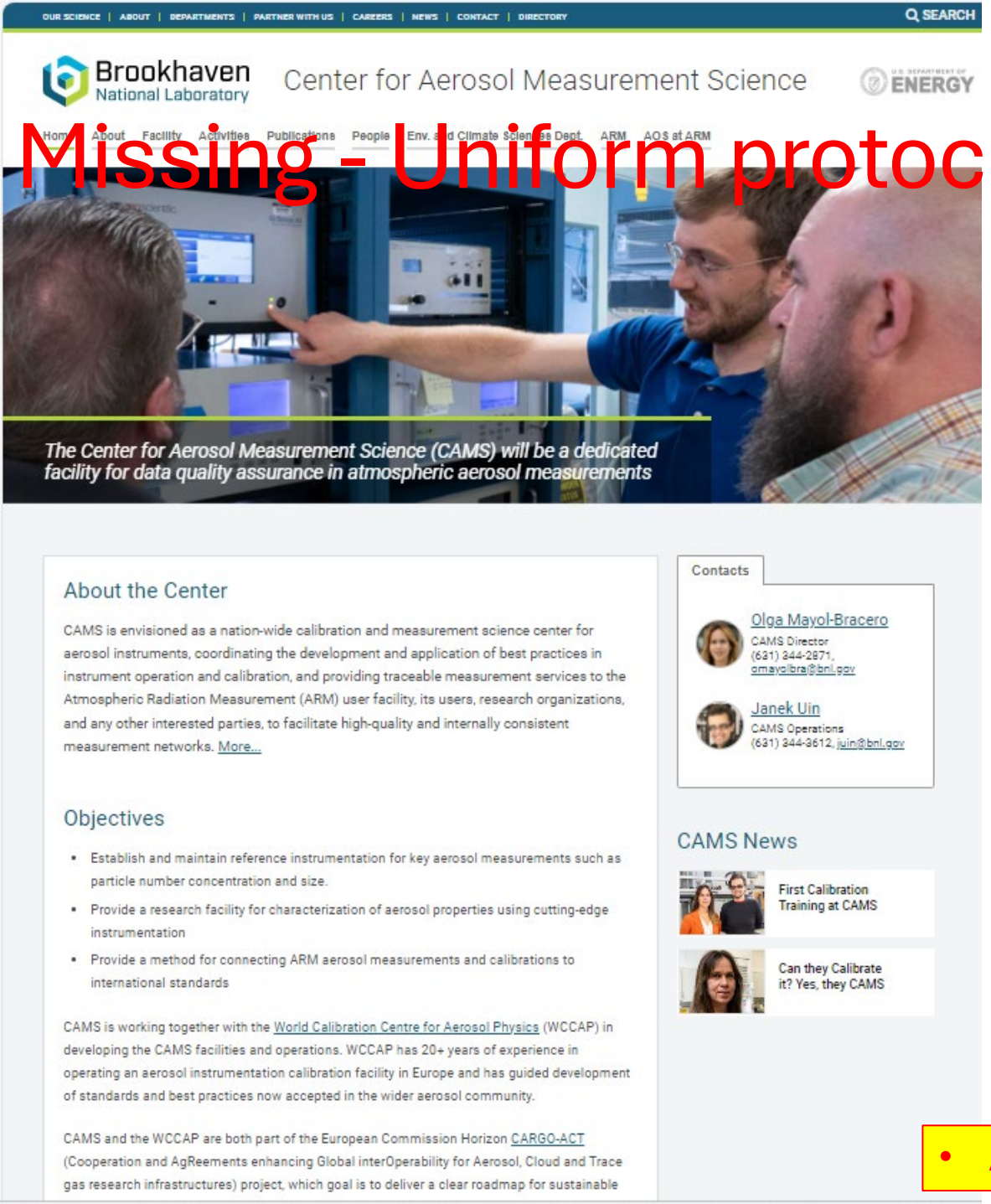
ARM
CLIMATE RESEARCH FACILITY

Atmospheric Radiation Measurement User Facility

- **DOE ARM is a partner in the European CARGO-ACT**
- The goal of the CARGO-ACT is to deliver a clear roadmap for sustainable global cooperation between key ground-based aerosol, cloud, and trace gas research infrastructures, each having invested in infrastructure and services to support their observing networks with a long-term perspective, to consolidate into a sustainable global research infrastructure in the future
- CARGO-ACT will develop sustainable partnerships and decision-making processes with relevant partners, demonstrate the benefits of converging interoperability and standards to stakeholders and the global research community, establish the mechanisms for providing international access to distributed research infrastructures and develop a roadmap for upscaling towards an integrated global research infrastructure for aerosol, cloud, and trace gases.
- CARGO-ACT is coordinated by the Finnish Meteorological Institute in Finland. The project kick-off meeting is scheduled on May 17th, 2024, in Rennes, France
- http://www.cargo-act.eu/about/

- ARM could help lead similar coordinating projects in US

Missing - Uniform protocols for data – Example #2



- DOE BNL Center for Aerosol Measurement Science (CAMS)
- Part of the DOE ARM FY2024 Aerosol Operations Plan
- Connected to World Calibration Centre for Aerosol Physics (WCCAP)
- Part of the European Commission Horizon CARGO-ACT
- Could be a NATIONAL center for Aerosol Measurement Science – similar to WCCAP – with support from multiple national networks
- https://www.bnl.gov/envsci/cams/
- ARM can highlight and promote CAMS

Missing – Direct parnerships – Example #1

ABOUT

ARM is the world's premier ground-based observations facility advancing atmospheric and climate research.

The Atmospheric Radiation Measurement (ARM) user facility is a multi-laboratory U.S. Department of Energy (DOE) scientific user facility, and a key contributor to national and international climate research efforts.

READ THE ARM MISSION AND VISION | FIND RESOURCES FOR NEW ARM USERS

ATMOSPHERIC DATA COLLECTION

ARM data are currently collected from three atmospheric observatories—Southern Great Plains, North Slope of Alaska, and Eastern North Atlantic—that represent the broad range of climate conditions around the world, as well as from the three ARM mobile facilities and ARM aerial facilities. Data from these atmospheric observatories, as well as from past research campaigns and the former Tropical Western Pacific observatory, are available at no charge through the ARM Data Center via Data Discovery.

EXPLORE ARM ATMOSPHERIC OBSERVATORIES

ARM MANAGEMENT STRUCTURE

Nine DOE national laboratories share the responsibility of managing and operating ARM. Along with these laboratories, several constituent groups help provide scientific guidance and develop ARM priorities. ARM also collaborates with many national and international partners.

VIEW ARM ORGANIZATION | VIEW CONSTITUENT GROUPS | MEET PROGRAM MANAGER

FACILITY DOCUMENTS

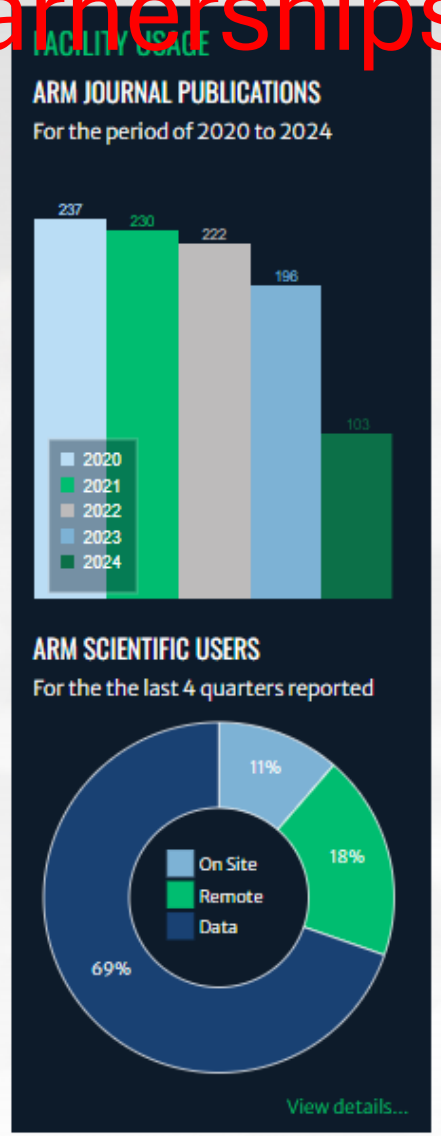
Along with scientific publications, ARM has three main types of operational documents:

1. **Program documents**, which include the Facility Management Plan, Decadal Vision planning document, and Decadal Vision progress report.
2. **Science reports**, which include science plans, field research campaign final reports, and workshop reports.
3. **Technical reports**, which describe how ARM data products are created and ARM scientific instruments are used.

HISTORY

ARM has provided the world's atmospheric scientists with continuous observations of cloud and aerosol properties and their impacts on the Earth's energy balance for almost 30 years.

DISCOVER ARM'S HISTORY



- DOE ARM is "***the world's premier ground-based observations facility advancing atmospheric and climate research***"
- We believe that DOE ARM can be strengthened by ***engaging with strategic partners***
- Can we get "Partnerships" or "Partners" on ABOUT website?
- Can we provide metrics associated with Partners to help track ARM efficiency and effectiveness?

- ARM can highlight and promote partnerships

Missing – Direct partnerships – Example #2

Modeling communities?

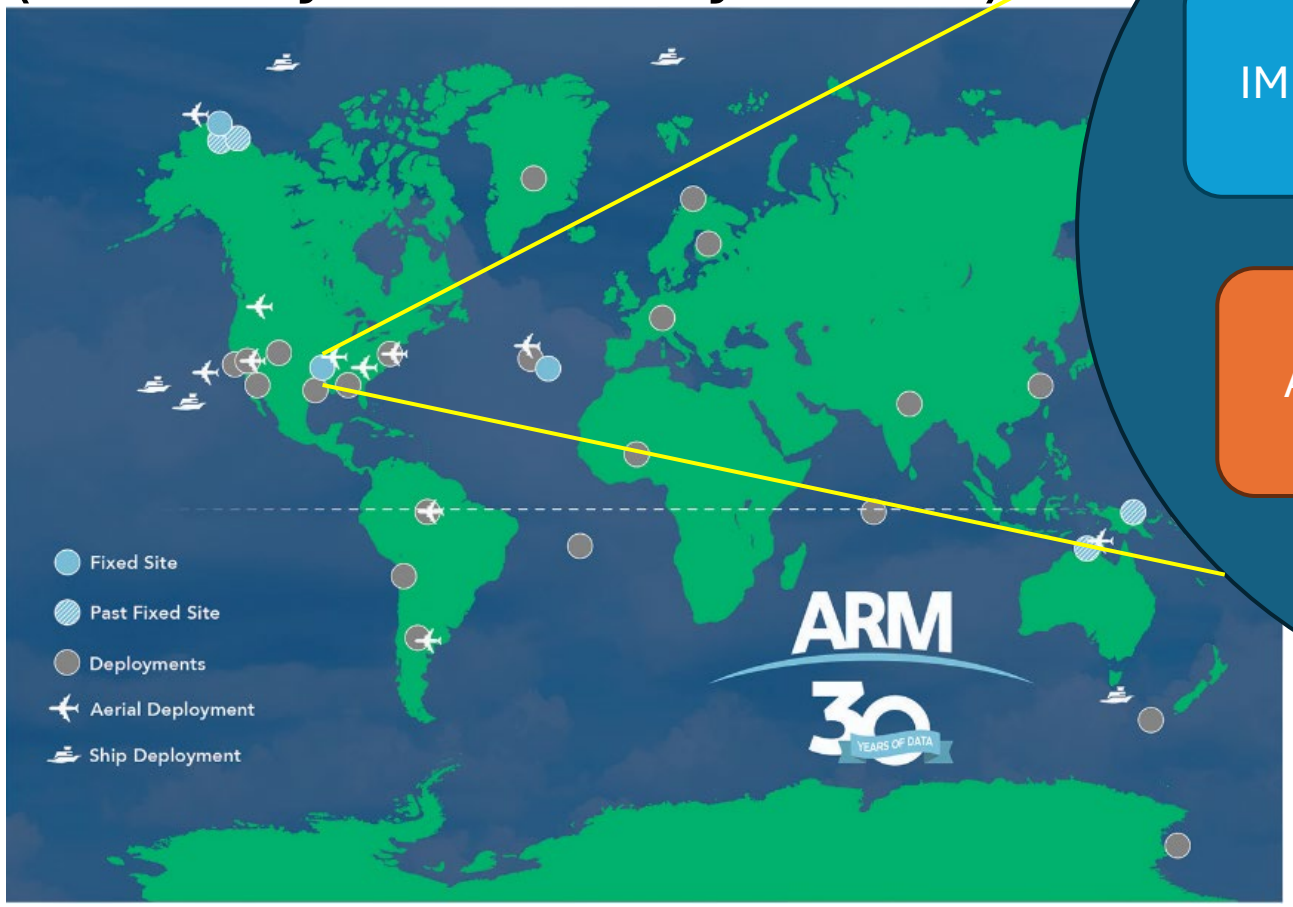
- AEROCOM
- CHIMP6+

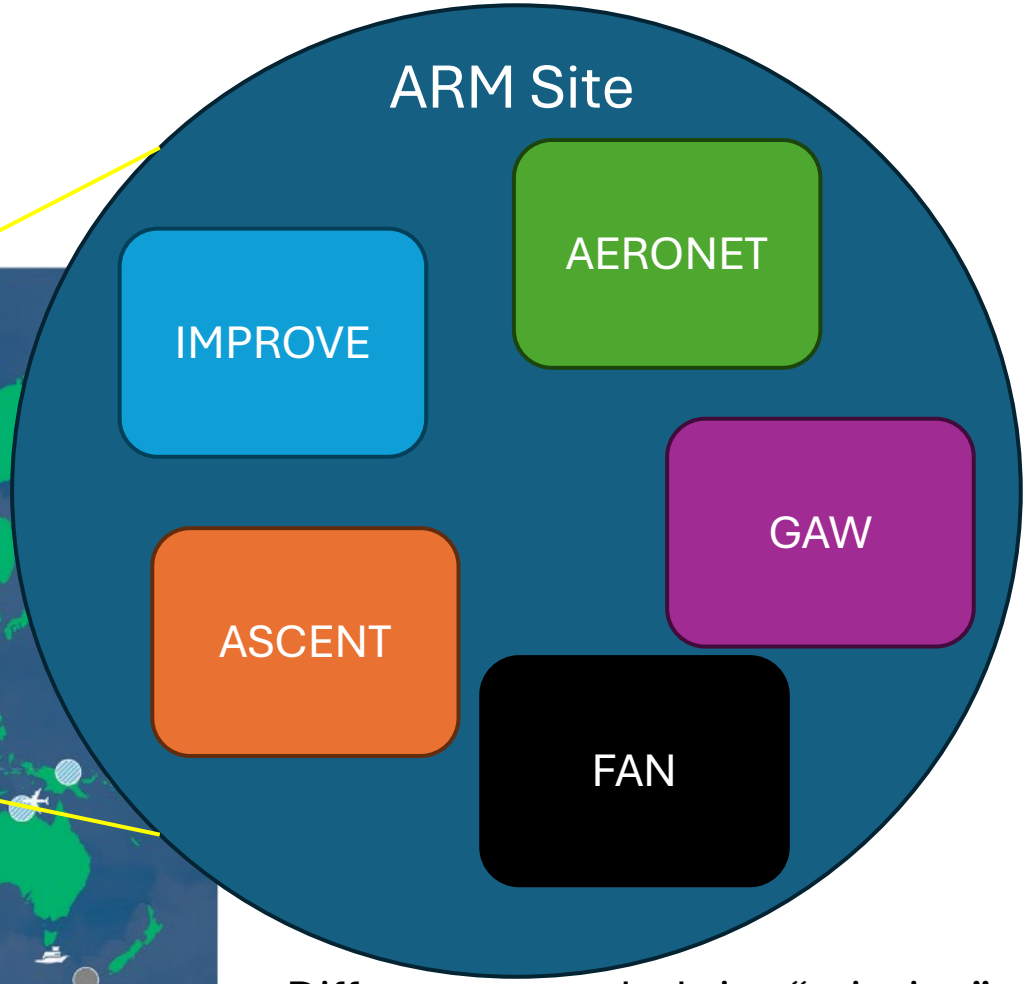
{Sorry, neither Gannet nor Tim is a Modeler…}

Potential Benefits from Strategic Partners

- ***Higher profile for ARM, including leadership roles and new metrics for success***
- Access to higher number and variability of measurement sites
- Access to more aerosol and trace gas measurements – including hosting other network sites at ARM observatories to augment current/missing measurements (e.g., IMPROVE at SGP for aerosol chemical composition)
- Coordinate data collection protocols with other entities
- More accessible data for scientists (i.e., analytic) and models (i.e., predictive)
- Larger community of scientists (including modelers) using ARM infrastructure and data
- Greater coordination across entities during large-scale Intensive Observational Periods (IOPs) and campaigns

How might this work?
ARM as host
(internally or externally funded)





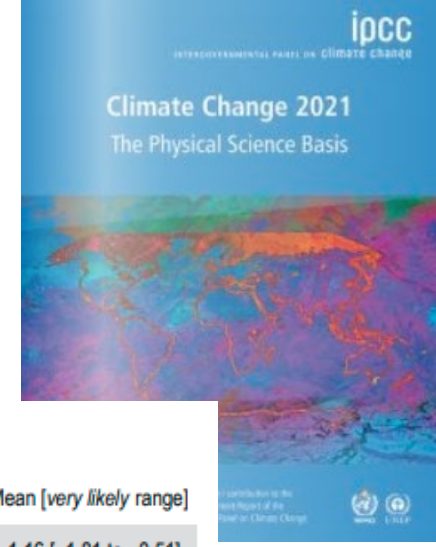
- Different networks bring “missing” measurements to ARM
- IOP’s at ARM sites then automatically become IOP’s at other network sites…
- Modeling infrastructure at ARM sites then automatically become modeling infrastructure at other network sites…

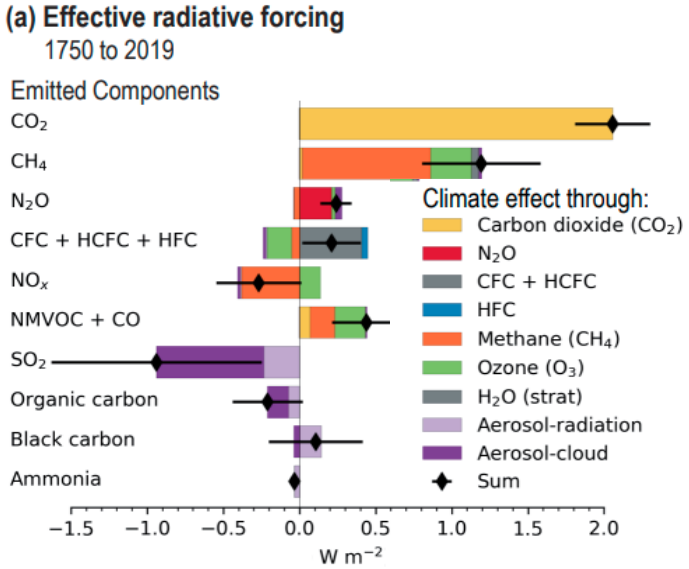
How might this work?
ARM as lead

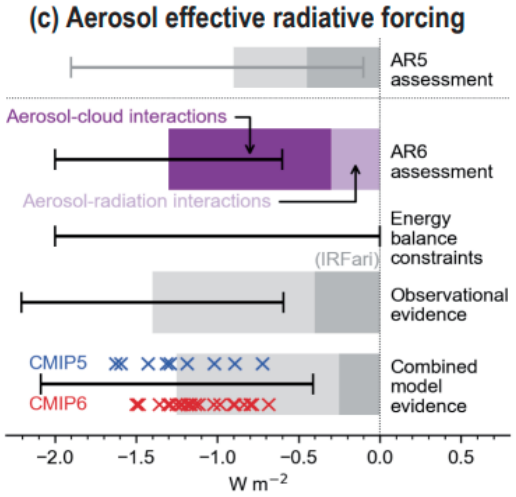
DOE ARM leads United States "CARGO-ACT"-type coordination project with unfunded collaborations with Europe

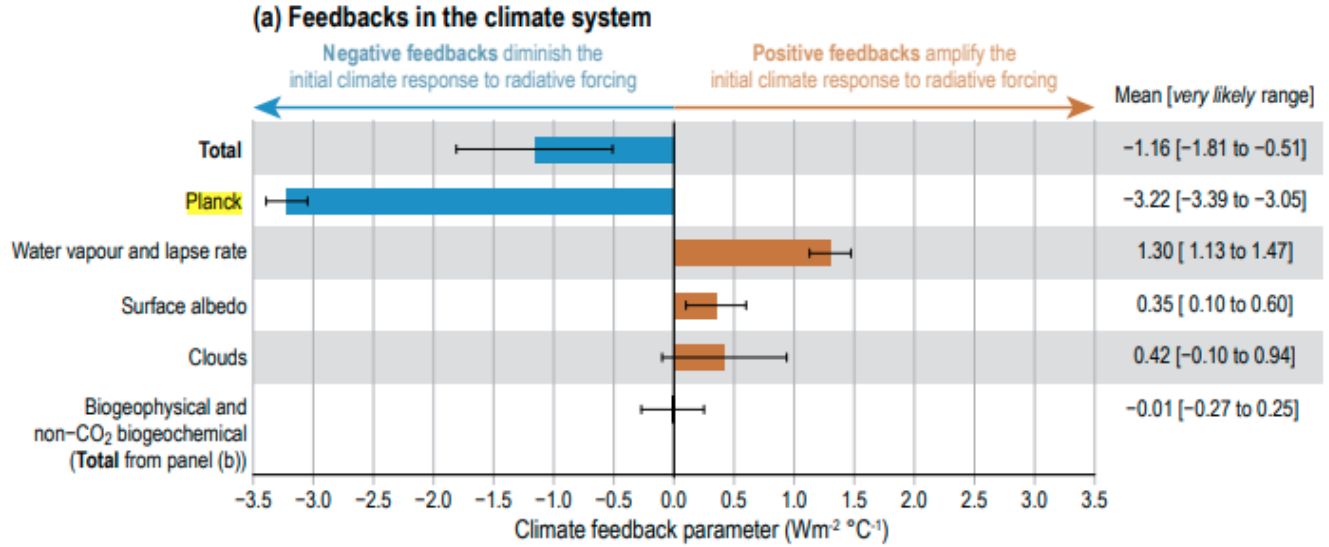
- ARM helps fund, support, grow aerosol networks within the US and Globally

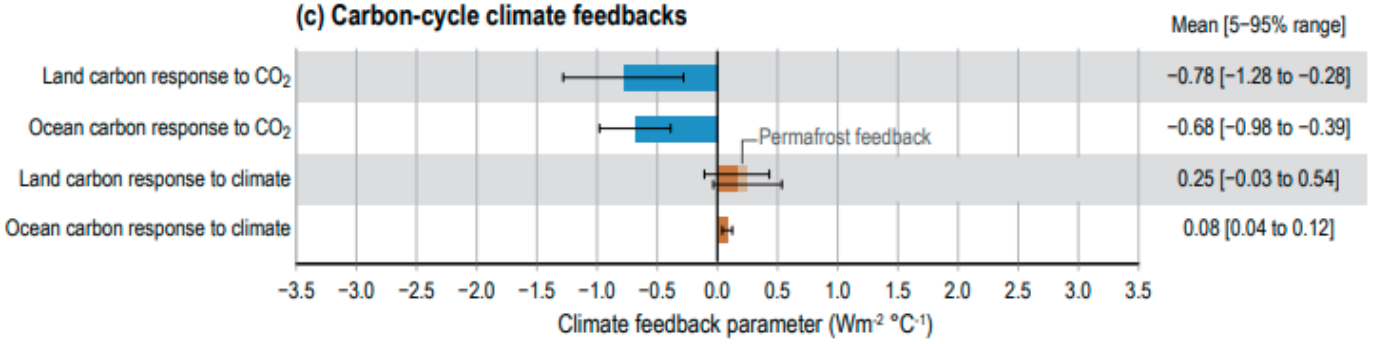
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS











https://www.ipcc.ch/report/ar6/wg1/

Outline

- 20 minutes – introductory presentation
  - Engage with strategic partners
- 30 minutes – 2 evenly split groups conduct brainstorm activities
  - *List of strategic opportunities:*
  - *List of problematic roadblocks:*
- 30 minutes – prioritizing activities
  - *Prioritized list of actionable items:*
- 10 minutes – summary and reflections

Session Summary:

- *Prioritized list of actionable items:*

1.

Final recommendations, comments and suggestions from breakout session (successes, failures):

Seed ideas for brainstorming sessions (for leaders to introduce as needed)

Session Brainstorming:

- *List of strategic opportunities:*

1. Increase number of partnerships with external entities – reengage with FAN and ASCENT
2. Continue to include DOE ARM ground-sites as sites in other networks (e.g., IMPROVE at SGP) to link and broaden scope and measurement capabilities
3. Participate in European CARGO-ACT project
4. Lead national project – similar to European CARGO-ACT project – to help coordinate networks
5. Highlight partnerships (e.g. on DOE ARM "about" website) – to our knowledge there is no place on the ARM websites that acknowledge existing external partners (outside of DOE)…
6. "VAP or data level or bundle" to convert ARM data, commonly at rapid 1 Hz rates, into GAW format, typically averaged to 1 hour – leaving data in ARM database (i.e., control), but more readily available to external users
7. Continue to support BNL CAMS with international collaborations
8. DOE ARM aerosol related BAMS paper – description of the process…

Session Brainstorming:

- *List of problematic roadblocks:*

1. Funding (and politics)
2. Mission overlap with other government agencies or external entities
3. Data formats and ease of use differ from network to network
4. Lack of similar measurements (ARM – ASCENT different instruments)
5. Lack of fully established protocols for calibrations and uncertainty
6. Lack of metrics (outside of publications) to help guide ARM's direction and achievements
7. DOE lab funding as specific block tasks – breaks up data collection/QA/dissemination

Extra Slides

DOE BER science mission

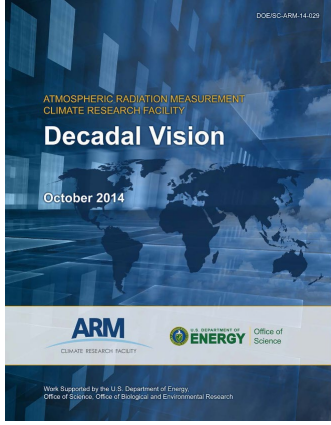
- The mission of the U.S. Department of Energy's (DOE) Biological and Environmental Research (BER) program is to:

"support transformative science and scientific user facilities to achieve a predictive understanding of complex biological, earth, and environmental systems for energy and infrastructure security, independence, and prosperity."

- Aligned with the BER central mission, the Earth and Environmental Systems Sciences Division (EESSD) plays a vital role in supporting the fundamental research to understand and predict Earth's climate and environmental systems, and is also in a unique position to inform the development of sustainable solutions to the nation's energy and environmental challenges. Specifically, EESSD manages two scientific user facilities: the **Atmospheric Radiation Measurement (ARM)** user facility and the Environmental Molecular Sciences Laboratory (EMSL).

Mei, F. (2020). ARM Aerial Instrument Workshop Report.
(https://science.osti.gov/ber)

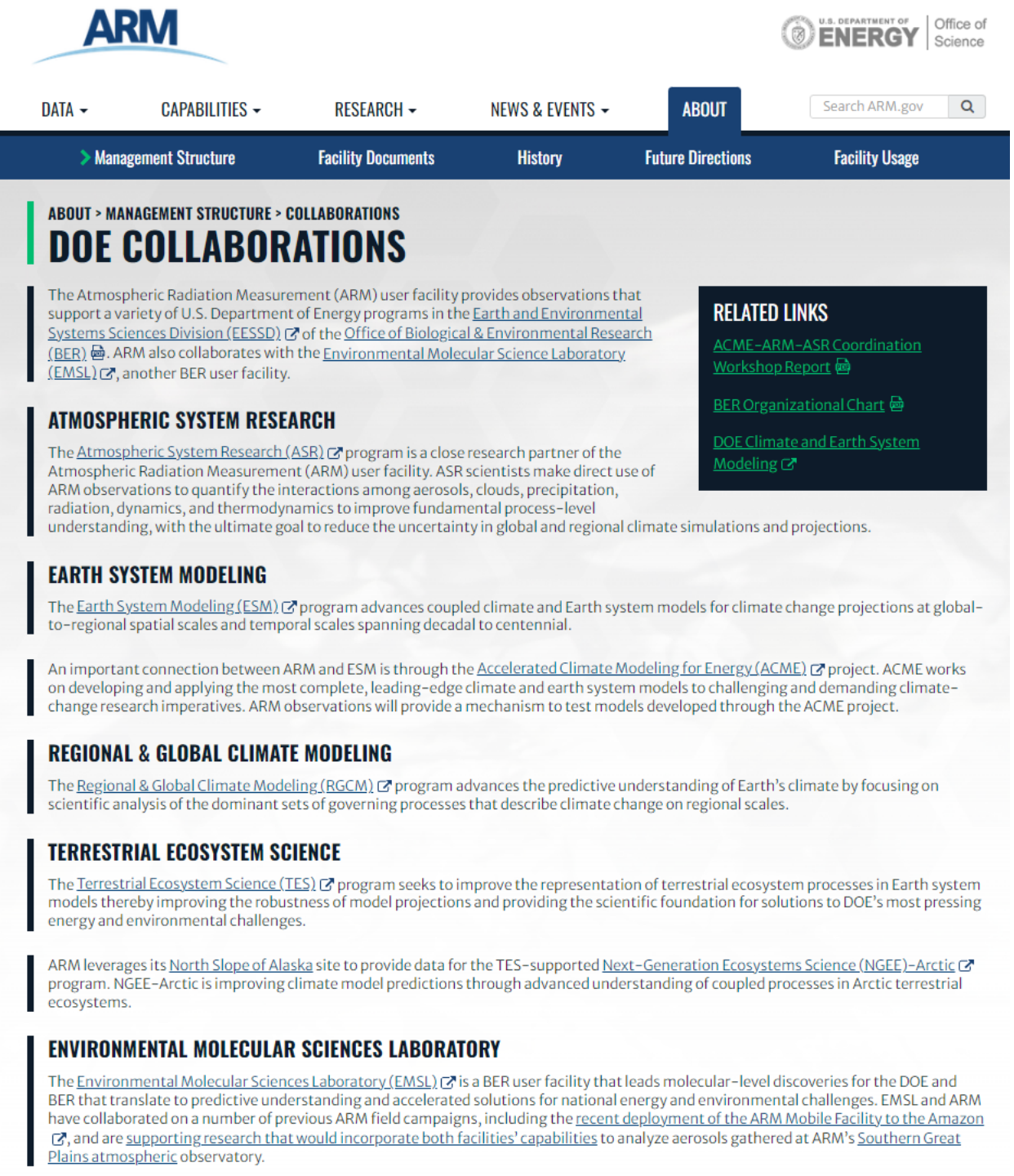
2014 ARM Decadal Vision



(To provide) the climate research community with strategically located in situ and remote-sensing observatories designed to improve the understanding and representation, in climate and Earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface.

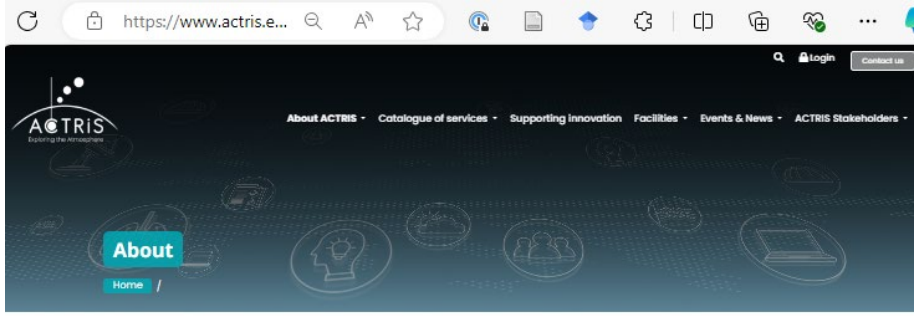
The ARM Facility is currently undergoing a reconfiguration that is designed to accelerate the application of ARM observations and data processing for the understanding of key atmospheric processes and the representation of these processes in global climate models. This enhanced impact on the research community will be achieved by:

1. Enhancing ARM observations and measurement strategies to enable the routine operation of high-resolution models and to optimize the use of ARM data for the evaluation of these models.
2. Producing routine high-resolution model simulations over domains coincident with ARM sites.
3. Developing data products and analysis tools that enable the evaluation of models using ARM data.



- ARM DOE Collaborations
- BNL CAMS?!?

https://www.actris.eu/about



What is ACTRIS?

The Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is the pan-European research infrastructure (RI) producing high-quality data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres.

ACTRIS enables free-access to high-class long-term atmospheric data through a single entry point. We offer access to our world-class facilities providing researches, from academia as well as from the private sector, with the best research environments and expertise promoting cutting-edge science and international collaborations.

Learn more

Who we are
What we do
Our Services

Why ACTRIS?

The atmosphere is a highly complex system driven by countless chemical and physical processes. Atmospheric process understanding and predictions use complex models that are underpinned by observations. Without high-quality observation data to constrain predictive models, any forecast of the atmosphere is highly unreliable.

ACTRIS contributes:

- to reducing uncertainties in emission sources, to understanding deposition processes that remove short-lived constituents from the atmosphere and to quantify their potential impacts on ecosystems.
- by bringing essential information for understanding global biogeochemical interactions between the atmosphere and ecosystems, and how climate–ecosystem feedback loops may change atmospheric composition in the future.
- by supporting the development of the required level of understanding of sources of the air pollutants that negatively affect human health.
- with the necessary observations to complement Earth Observations from space, providing unique ground-truthing of remote sensing information collected by current and future satellite missions.

ACTRIS helps responding to the grand-challenges faced nowadays by our society: ACTRIS enables a deeper understanding in atmospheric processes, improving our resiliency to climate change, and air quality, contributing to reduce the effects of air pollution on public health and ecosystems

Read more

Science & Innovation
Our Facilities
ACTRIS scientific relevance

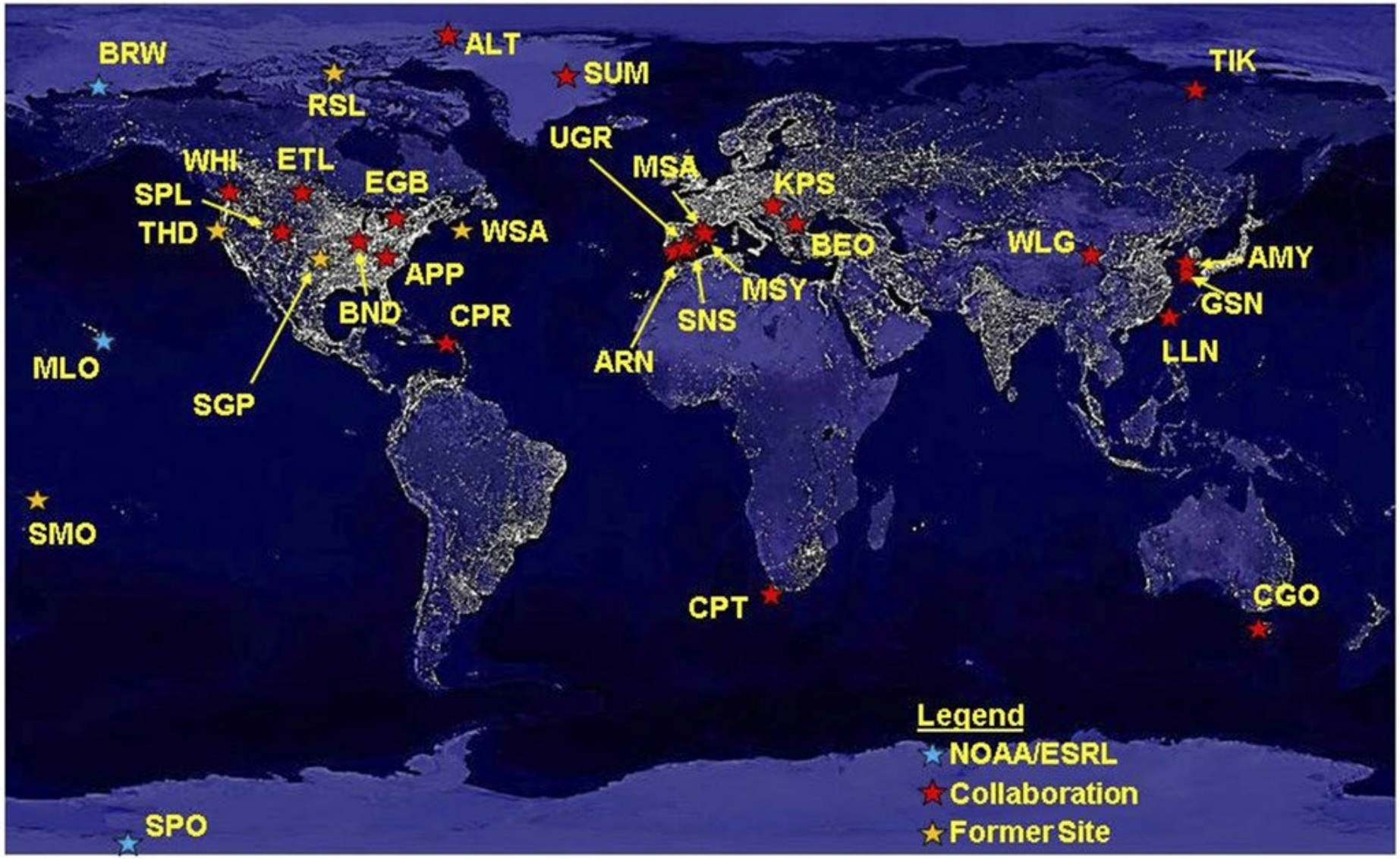
What do we offer?

We offer access to high-quality long-term atmospheric data through a single entry point and to our state-of-the-art facilities. ACTRIS develops new technologies and algorithms for monitoring activities relevant for climate and air quality models, satellite retrievals and forecast systems, serving a vast community of users working in research, space agencies, operational services, public and private sectors. ACTRIS facilitates the integration of the community around common strategic objectives, which will bring the economy of scale and harmonious development of the infrastructure, including the

https://ascent.research.gatech.edu/about

Site Number	Local Site Name	Current Network	Instrument Mentor	Comments
1	Delta Junction	NEON, AERONET	Jingqiu Mao	Remote, arctic, background, boreal forest, intercontinental transport, EPSCoR
2	Cheeka Peak/Makah	NCore, IMPROVE	Joel Thornton	Marine background/inflow, smoke at times, tribal site
3	Pico Rivera	SCAQMD	John Seinfeld & Rick Flagan	Paired site 1: urban, anthropogenic, VCP, wildfires
4	Rubidoux	SCAQMD, NCore, PAMS	Roya Bahreini	Paired site 2: urban, anthropogenic, aged OA, wildfires
5	Joshua Tree	IMPROVE, CASTNET	Lelia Hawkins	Paired site 3: aged OA, downwind of LA and Riverside
6	Yellowstone	IMPROVE, CASTNET	Shane Murphy	Background site with wildfires, EPSCoR
7	La Casa	NCore	Jose Jimenez	Urban, wintertime pollution, oil and gas, wildfires, agriculture
8	Houston	HNET	Jimmy Flynn & Robert Griffin	Urban, petrochemical industry, maritime shipping
9	Lawrenceville	IMPROVE, NCore, PAMS, NATTS	Albert Presto & Allen Robinson	Urban, oil and gas, fracking, heavy industry
10	Queens College	NCore, AERONET	Drew Gentner	Urban, coastal, VCP
11	South DeKalb	IMPROVE, NCore, PAMS, NATTS	Nga Lee Ng	Paired site 1: urban, biogenic
12	Look Rock	IMPROVE, NCore, CASTNET	Jason Surratt	Paired site 2: background, biogenic

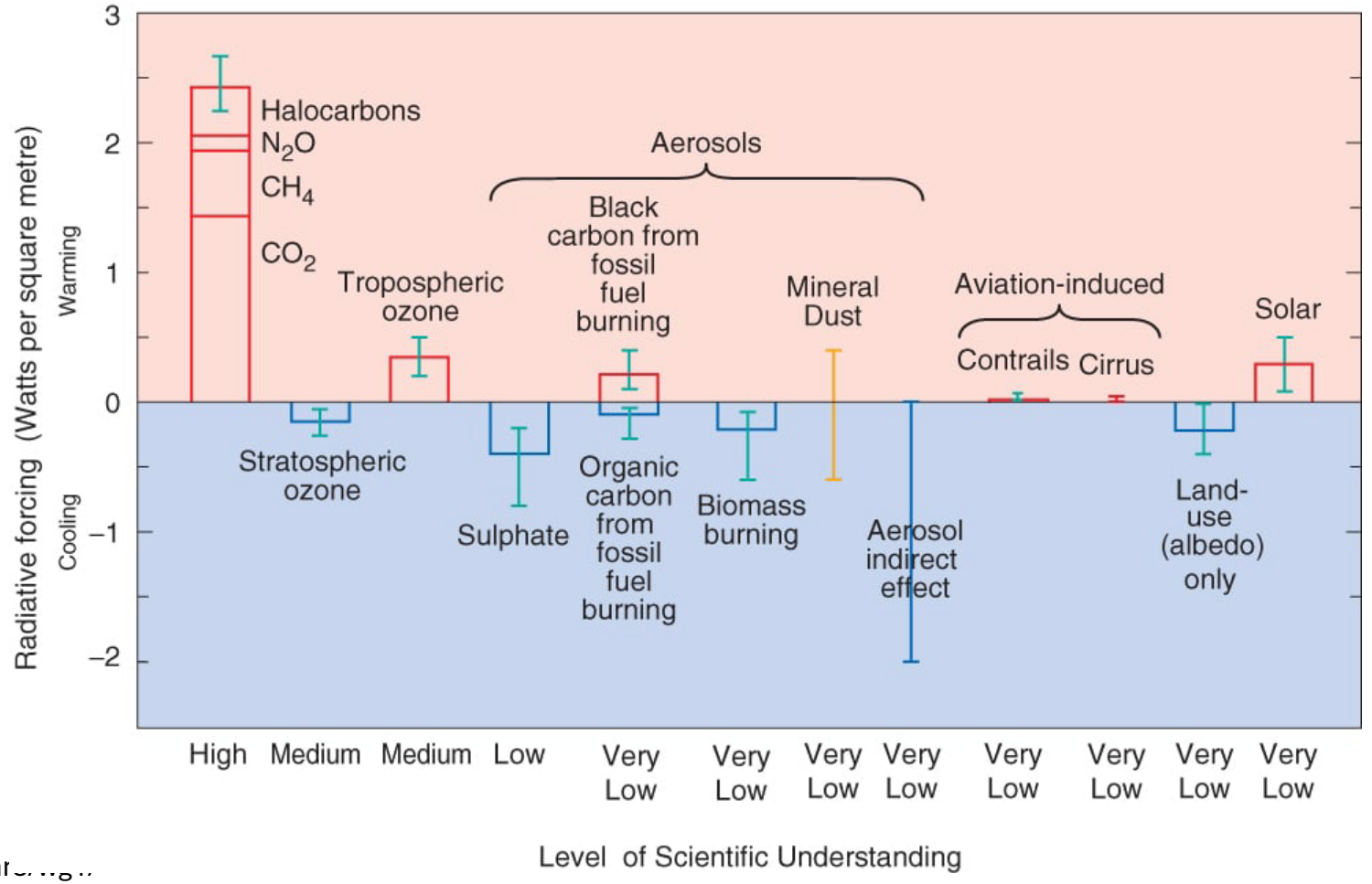
Fig. 1.



Map of current (January 2018) and former long-term sites in the FAN superimposed on a nighttime lights image (Credit: NASA Earth Observatory and NOAA). Former sites Resolute Bay in Canada (RSL), SGP, and WSA were FAN collaborations, while THD and SMO were solely NOAA observations.

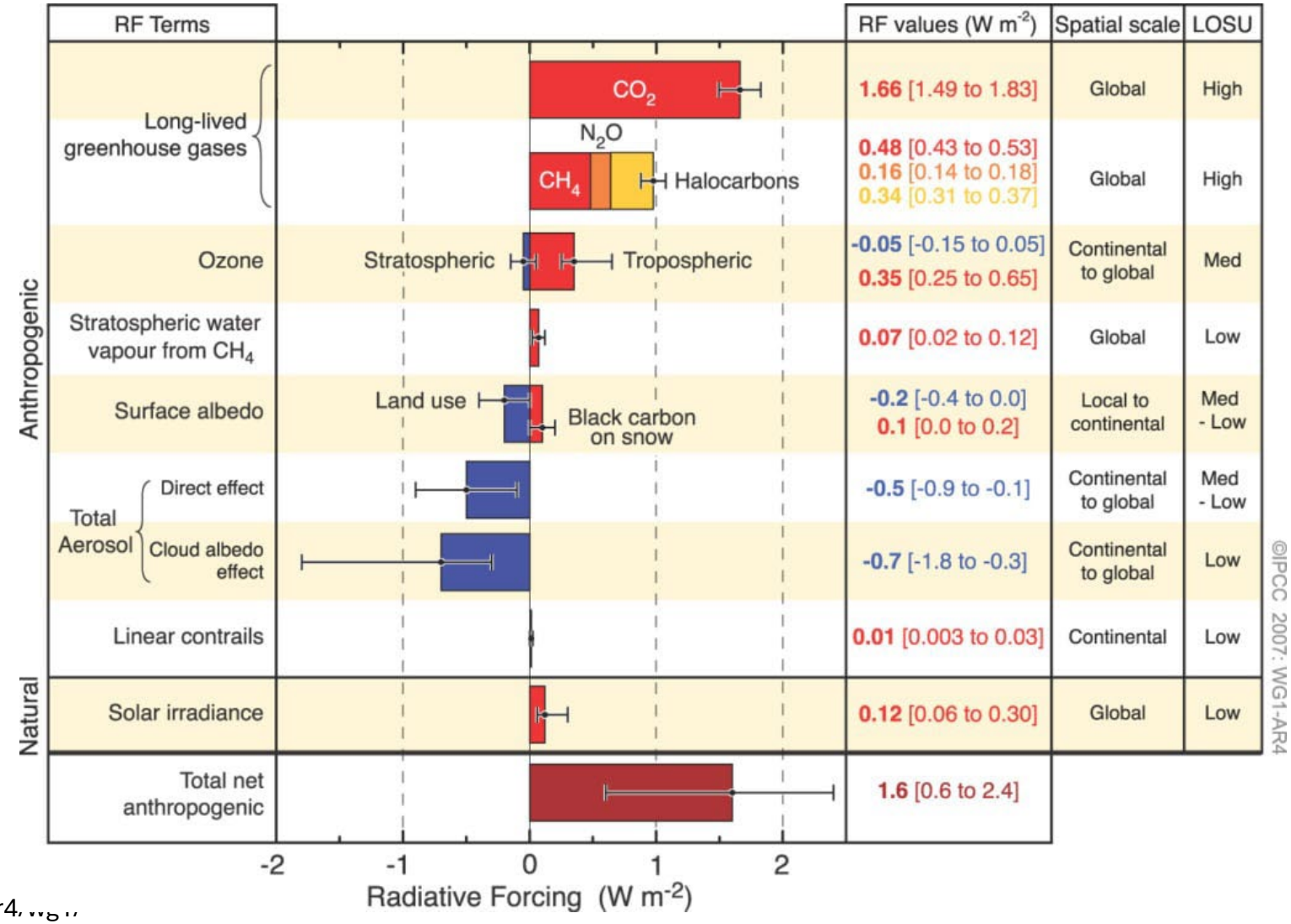
TAR CLIMATE CHANGE 2001: THE SCIENCE BASIS

The global mean radiative forcing of the climate system for the year 2000, relative to 1750



https://www.ipcc.ch/report/ar...

AR4 CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS



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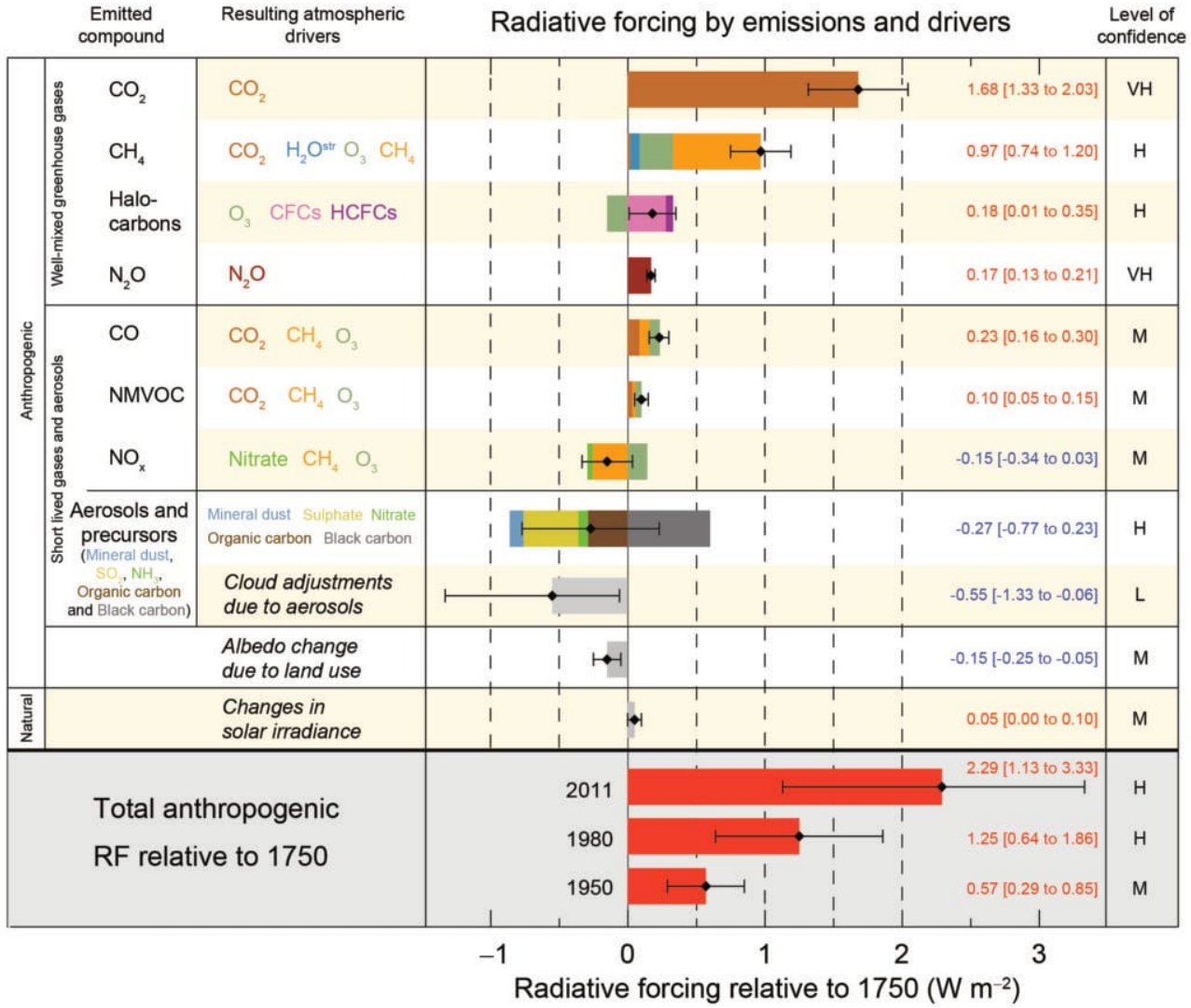
AR5 CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS



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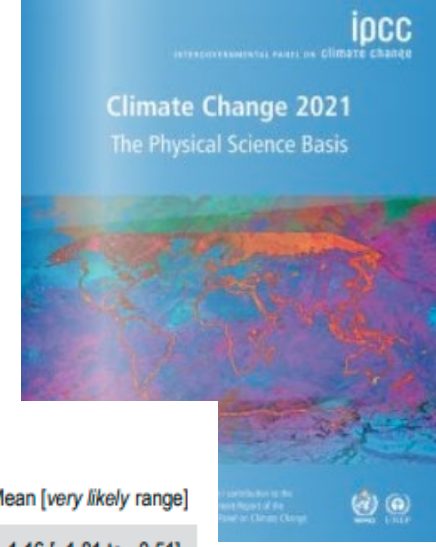
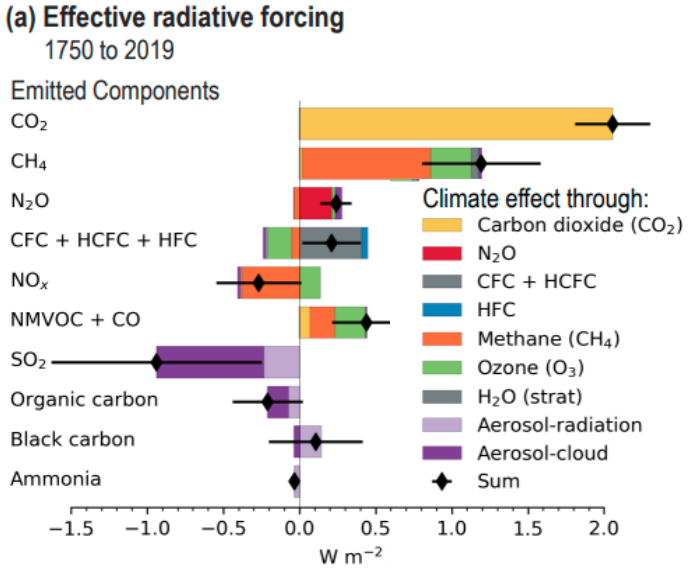
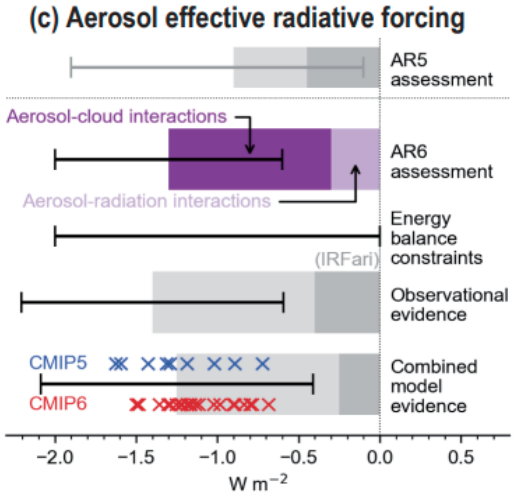
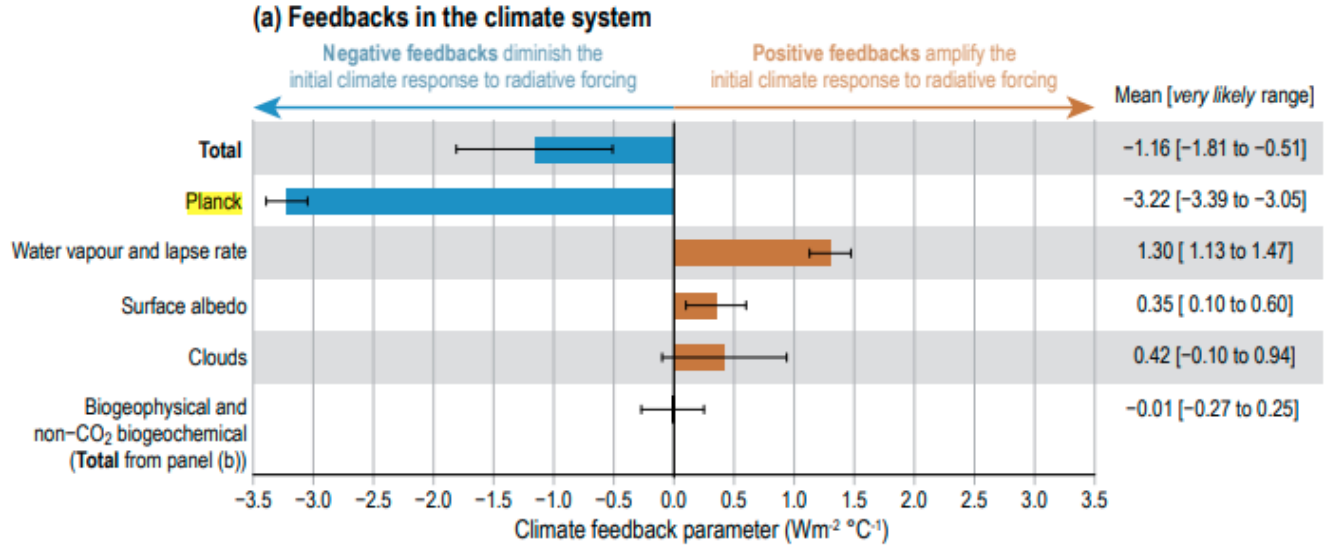
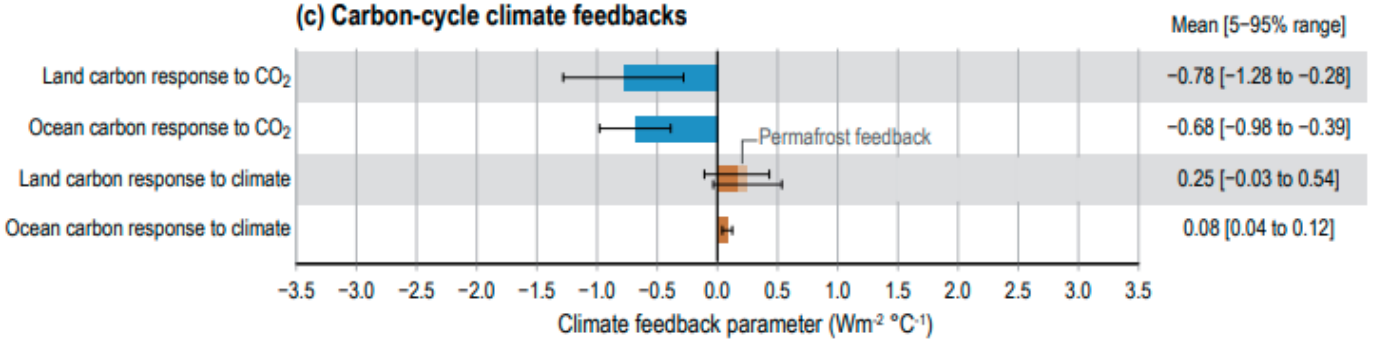
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS











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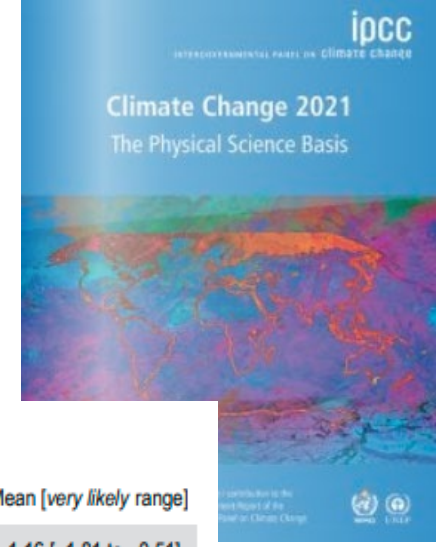
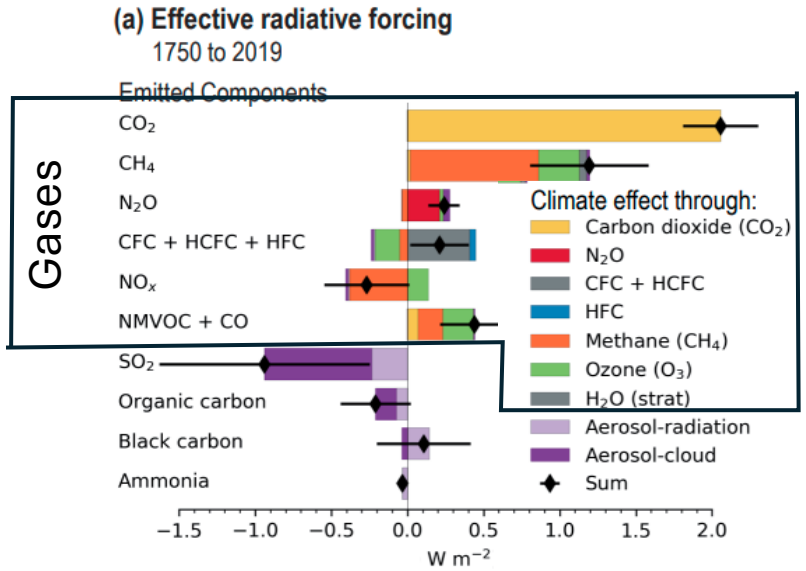
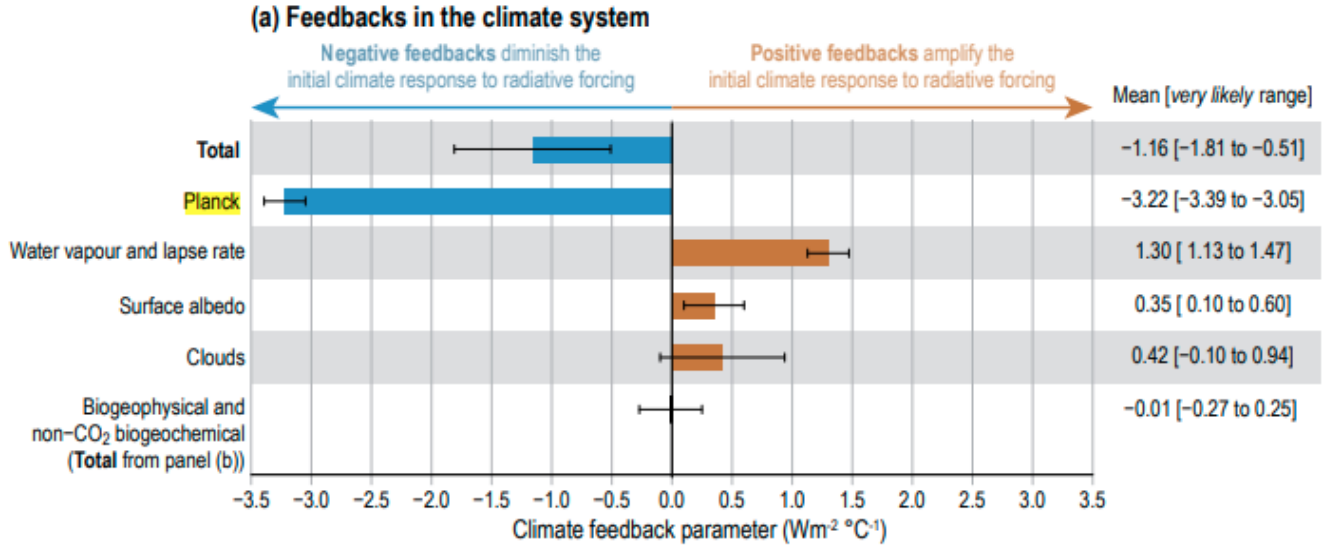
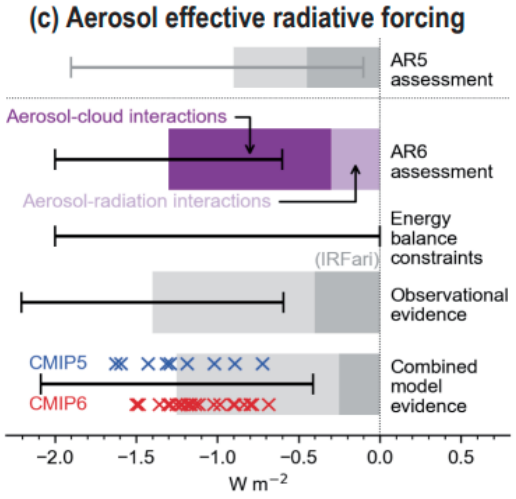
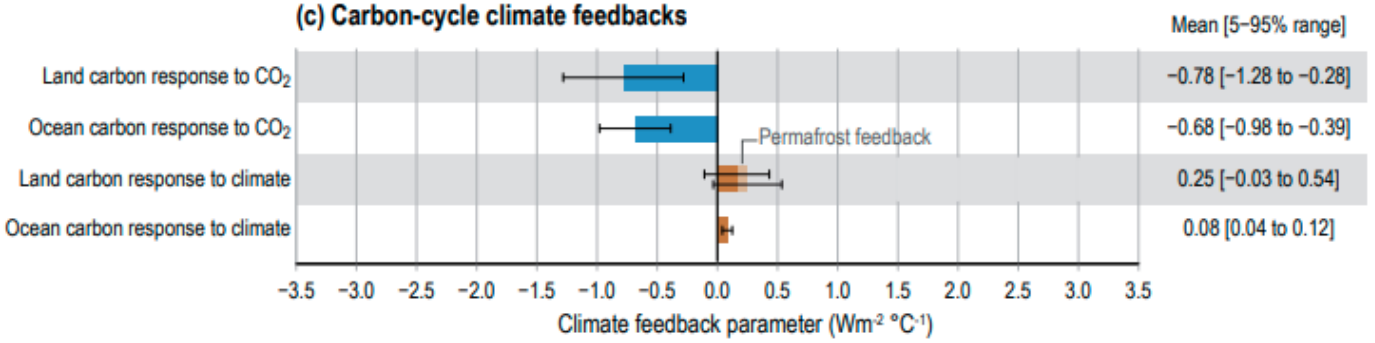
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS











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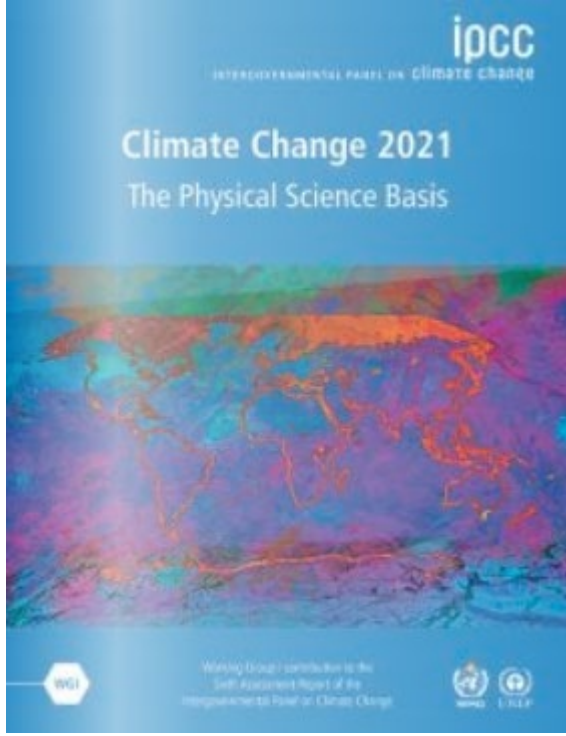
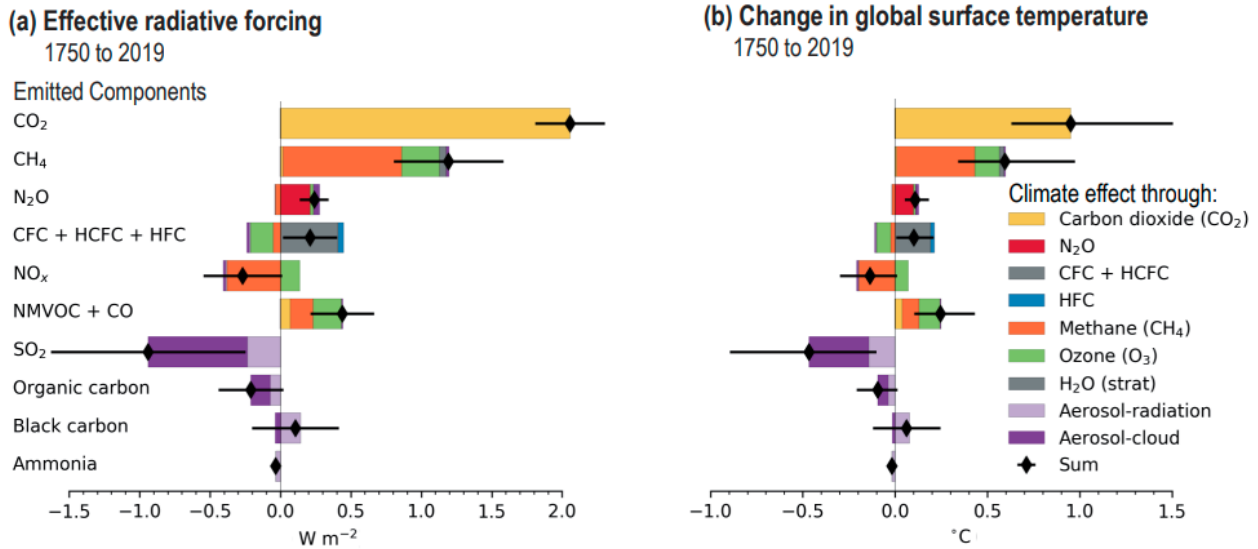
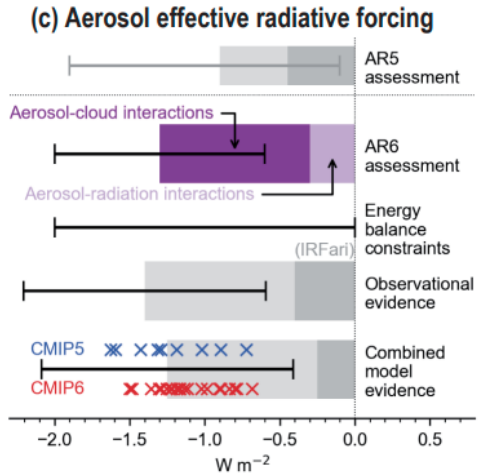
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS







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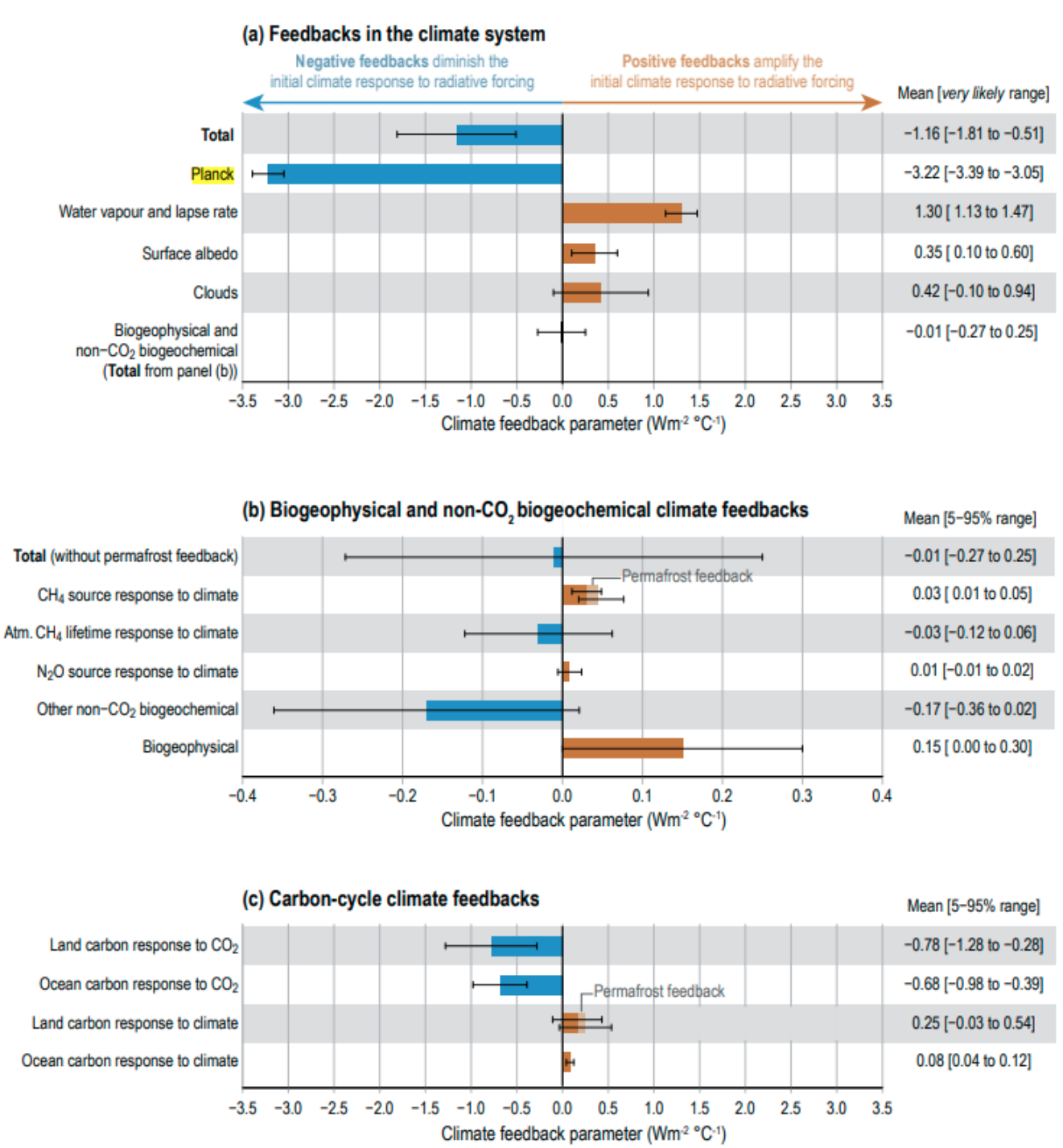
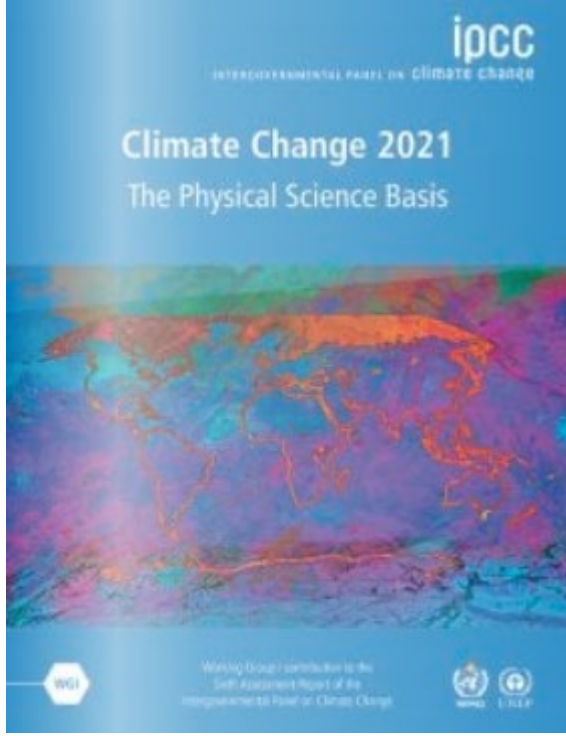
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS





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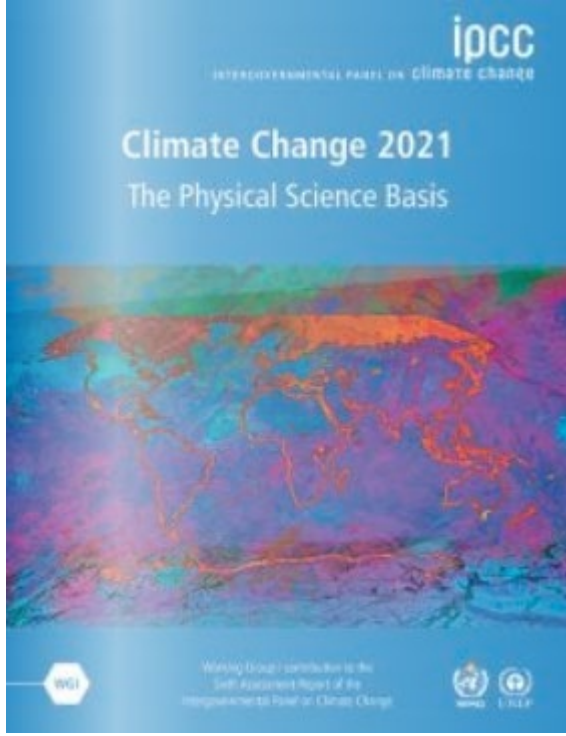
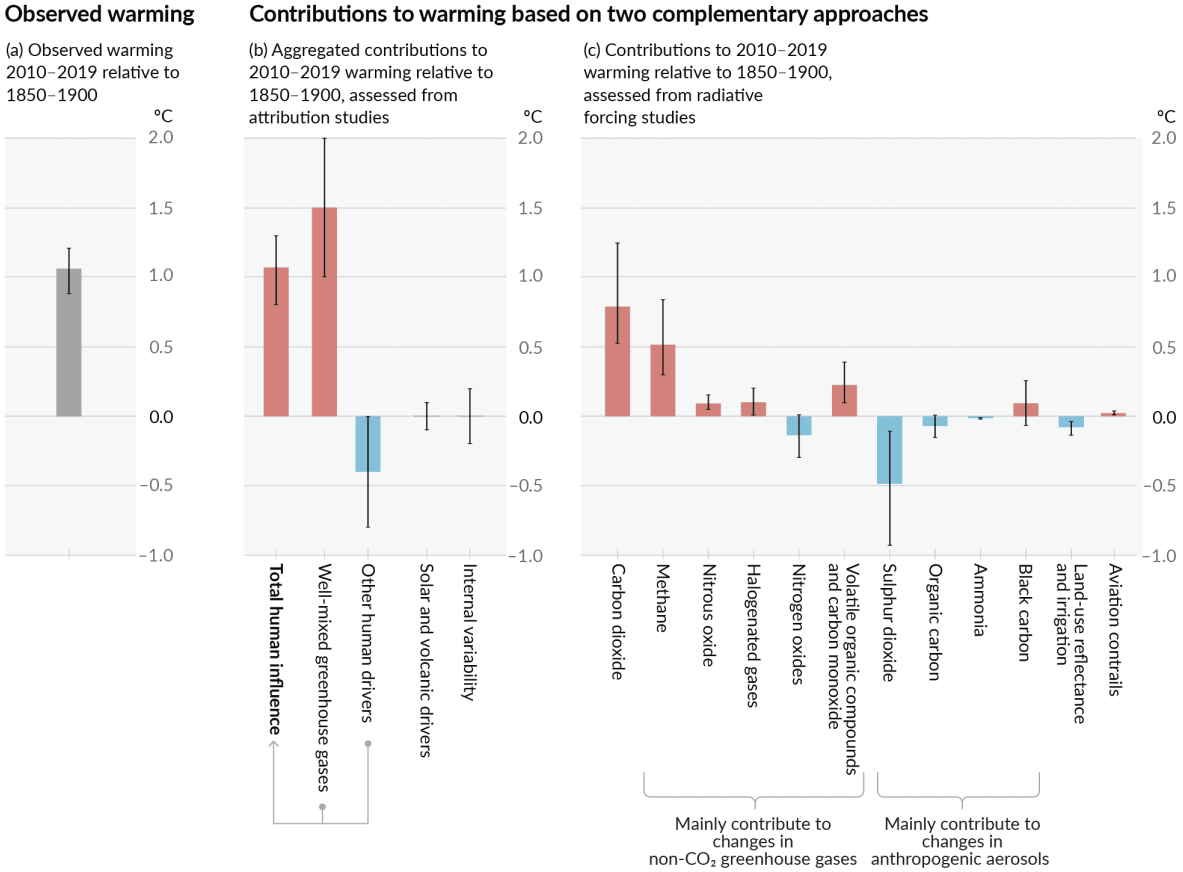
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS



Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling



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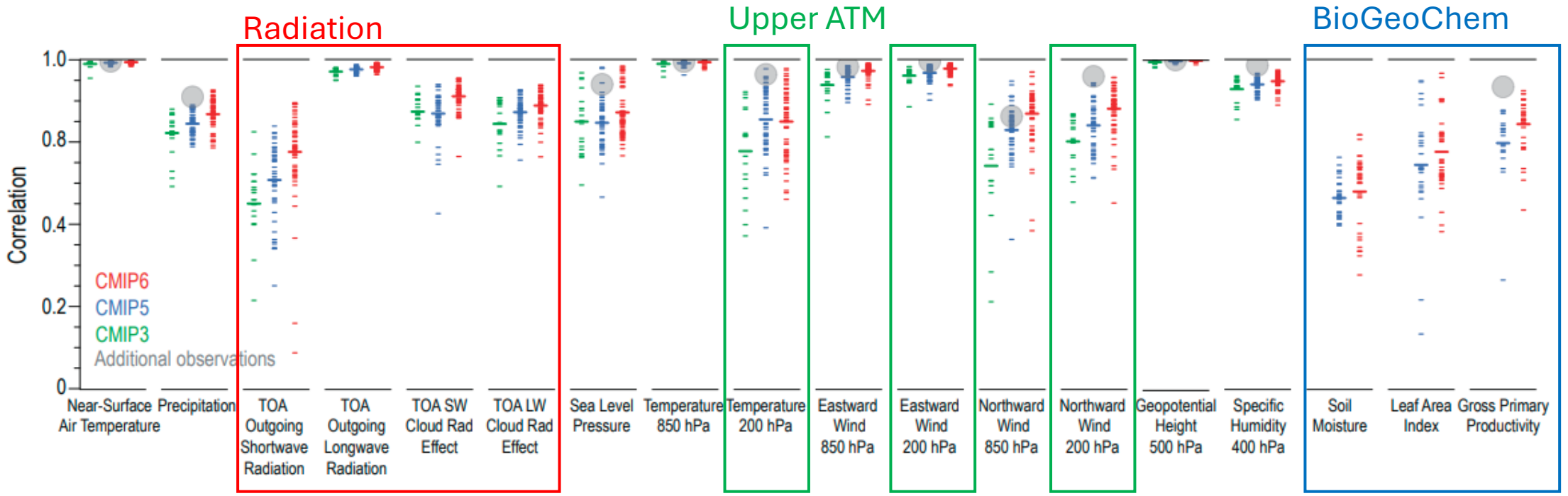
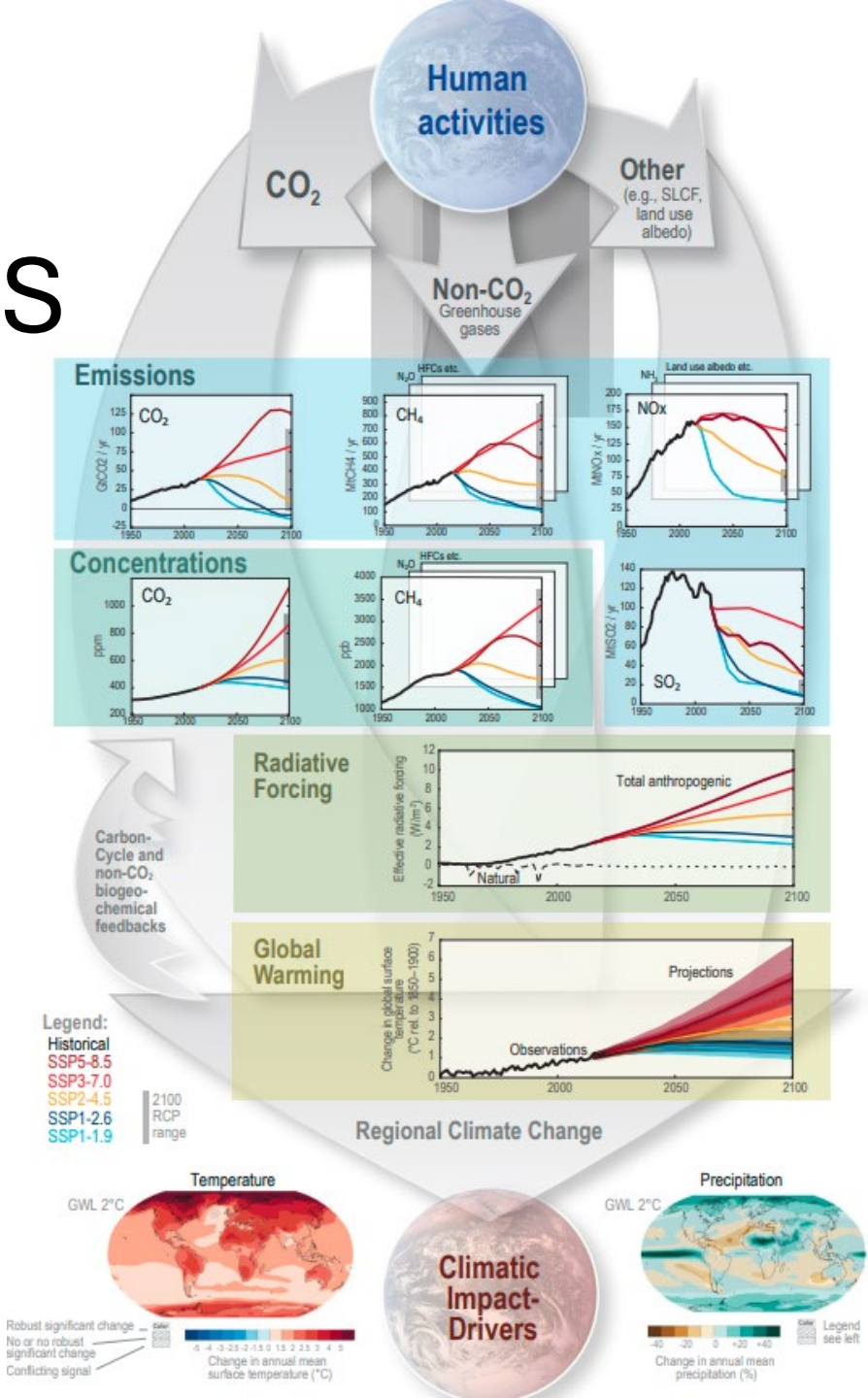
AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS

Progress in climate modeling: Pattern correlation with observational reference

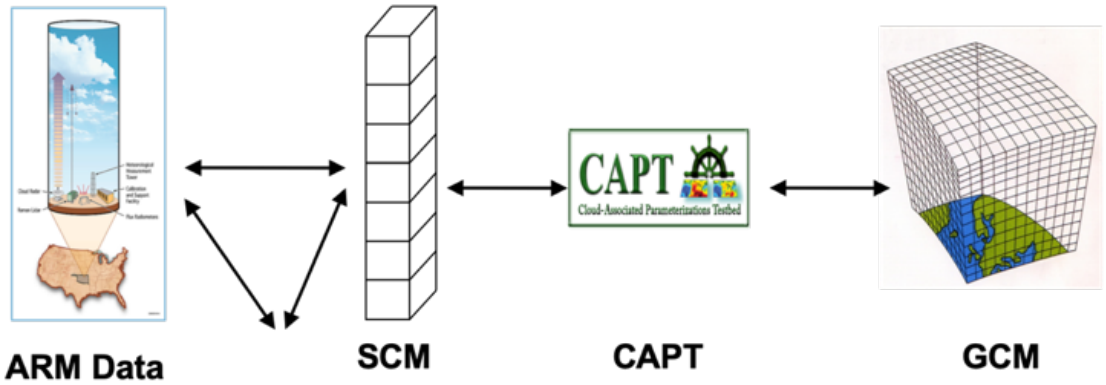


AR6 CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS

The climate change cause–effect chain:



Developing Forcing and Evaluation Data and Tools to Support Cloud Modeling



The schematic diagram illustrates how ARM data and process modeling testbeds are used in global climate model development. The goal of the LLNL ARM infrastructure project is to provide necessary ARM data and tools to support process modeling studies.

Diagram for Lawrence Livermore National Laboratory's (LLNL) Atmospheric Radiation Measurement (ARM) Infrastructure Project. (Image credit: Shaocheng Xie of Lawrence Livermore National Laboratory)

https://portal.nersc.gov/project/capt/ARMVAP/index.html