WRITTEN STATEMENT OF
DR. ARIEL STEIN
DIRECTOR OF NOAA'S AIR RESOURCES LABORATORY
ACTING DIRECTOR OF NOAA'S GLOBAL MONITORING LABORATORY

ON THE
ASSESSING FEDERAL PROGRAMS FOR MEASURING GREENHOUSE GAS SOURCES AND SINKS

BEFORE THE
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

1. INTRODUCTION

Chairwomen Sherrill and Stevens, Ranking Members Bice and Feenstra, and Members of the Subcommittees, thank you for the opportunity to testify today regarding Federal programs focused on monitoring, measuring, and verifying sources (emissions to the atmosphere) and sinks (removal from the atmosphere) of greenhouse gases (GHGs).

NOAA's mission is science, service, and stewardship. Our reach goes from the surface of the sun to the depths of the ocean floor as we work to keep the public informed of the changing environment around them. We know that major elements of our Earth's life support system are changing in ways never before observed in recorded history. Foundational environmental parameters – atmospheric composition, water and land surface temperatures, ocean chemical balance, global sea levels, polar sea-ice cover, and global land use distribution – are all changing at unprecedented rates.

2. LEGACY OF GREENHOUSE GAS MONITORING AT NOAA

NOAA's long-term atmospheric observations serve as a baseline and record, which can be used to monitor natural and anthropogenic emissions of GHGs as well as their uptake by natural land- and ocean-based processes and the effectiveness of efforts to reduce climate change through GHG mitigation or other means.

NOAA's Mauna Loa Observatory is the global benchmark location for monitoring atmospheric composition. With CO_2 measurements dating back to 1958, the Mauna Loa Observatory offers a unique location 11,135 feet above sea level and far from most human influences to monitor sunlight and air. The NOAA observatory continues today as a cornerstone of NOAA's Global

Greenhouse Gas Reference Network, measuring a range of GHGs, ozone depleting gases, air pollutants, and the sun's radiation. NOAA scientists take continuous measurements from Mauna Loa and more than 70 sites around the world.

NOAA's GHG data feed models to predict long-term changes in climate that have the potential to impact long-term planning needed for industries like shipping, fishing, agriculture, construction, finance, and water resources. Other federal agencies, states and local governments, communities, U.S. industry, and international partners depend on measurements we collect through our Global Greenhouse Gas Reference Network.

3. NOAA'S ROLE

Building on this legacy, NOAA is a trusted source for monitoring the long-term trends of concentrations of CO_2 and other GHGs in the atmosphere. We are the World Meteorological Organization's Central Calibration Laboratory for GHG concentration measurements, and we disseminate field standards for GHG measurements. More than 60 years of recorded measurements at NOAA's Mauna Loa Observatory and other remote sites - such as the South Pole and the northernmost point of Alaska - represent some of the most important and fundamental sources of information to understand and demonstrate how humans have changed the atmosphere.

Observations at these remote sites also provide NOAA with a measure of the cumulative direct impact of rising GHG levels on Earth's climate. NOAA uses this foundational climate information to develop products and tools to help understand the human contributions to warming from long-lived GHGs and inform decision-making. In 2006, NOAA developed the Annual Greenhouse Gas Index (AGGI) as a way to help policymakers, educators and the public appreciate how changes in atmospheric composition change the amount of heat trapped in our atmosphere. The AGGI has shown that the human contribution to warming from long-lived GHGs in the atmosphere was 49 percent higher in 2021 than in 1990.

As the global leader in monitoring long-term trends of atmospheric concentrations of CO_2, methane, and other potent GHGs, NOAA plays a vital role in attributing and understanding emissions of these gases that are critical to Earth's radiative balance (the balance of incoming solar energy and outgoing energy reflected from the Earth's surface). For example, in 2018, observations and analyses from NOAA's Global Greenhouse Gas Reference Network and international partners indicated that atmospheric concentrations of an ozone-destroying Chlorofluorocarbon (CFC-11) were not declining as fast as expected, providing evidence of increasing emissions arising from unreported production of CFC-11, which is a violation of the Montreal Protocol.[1] This discovery led to international pressure and eventually renewed

[1] See Emissions of an ozone-destroying chemical are rising again and Two additional regions of Asia were sources of banned ozone-destroying chemicals

enforcement and inspection measures. NOAA is also conducting research to understand various natural sinks, including monitoring and quantifying the natural GHG uptake of ocean- and land-based processes, carbon sequestration in coastal ecosystems, and the critical role of the ocean in removing CO_2.

By measuring atmospheric concentrations of over 60 different species of gases, NOAA's global network is essential for detecting not only changes in human-made emissions of GHGs over time but also how human-made emissions and human activities increase natural sources of GHGs (e.g., through what are referred to as feedbacks). This is important because warming-induced changes in the natural sources and sinks of CO_2 could in turn impact our collective ability to meet any desired climate target, such as keeping the global temperature increase to well below 2^oC relative to pre-industrial times. With this robust global monitoring network, NOAA is capable of distinguishing, for example, between relative concentrations of CO_2 coming from fossil fuels versus those coming from natural sources, such as the decay of organic matter. NOAA's research has shown that it is unlikely that fossil fuels are the largest contributor on a global basis to the rapid rise in methane that we have detected over the last decade. Instead, this methane is coming from microbes, indicating that agriculture, wetlands or landfills are more likely sources of the methane rise.

NOAA has recently built up technology that enables balloons to be launched and retrieved in the same location and that allows full profiles up to 100,000 feet to be captured and measured, providing an important touchstone to integrate satellite measurements into our observational network. NOAA is working with the airline industry to help expand the agency's GHG observing network by putting instruments on commercial aircraft to capture data as the planes ascend and descend. This new capability has the potential to provide orders of magnitude more observations of the atmosphere in climate-sensitive regions like the Arctic and the tropics as well as high-emitting regions surrounding many metropolitan airports. Not only will this provide NOAA with more high quality data, but these data may allow NOAA to detect GHG changes at higher temporal and spatial resolutions.

Accurate estimates of GHG concentrations allows scientists to better estimate emissions and removals essential for informing and evaluating specific measures and broader policy decisions to mitigate climate change impacts. NOAA plays a key role in delivering this information to policymakers and the public through the communication of our data and the development of tools and methods to quantify GHG sources and sinks. For example, NOAA's CarbonTracker is a modeling system that uses the global reference network and other data to model sources and sinks of carbon dioxide around the world. On a global scale, NOAA's CarbonTracker model uses data from approximately 150 sites across the globe to provide a 4-D picture of the two most important GHGs (CO_2 and methane) emitted by human activities at 3-hour intervals from January 2000 to the present. This tool is one baseline of comparison for atmospheric based

estimates of GHG emissions and removals across the globe, providing ground truth for satellites and emissions estimates. As I speak, NOAA is in the process of merging its CarbonTracker data assimilation system with its high-resolution Unified Forecast System to enable users to assess emissions at various scales and for different sectors. NOAA aims to contribute with new tools to provide reliable and timely estimates of GHG emissions and removals to support regional, national and global climate mitigation efforts.

Under the Infrastructure Investment and Jobs Act (IIJA), signed by President Biden on November 15, 2021, NOAA received funding to support efforts including integrated understanding of linkages between fires, drought, air quality, and land surface sensitivity in a post-fire environment; advancements in smoke emissions and air quality modeling; experimental improvement to climate and Earth system models to integrate fire dynamics and drivers more explicitly into model simulations in support of modeling and forecasting efforts. NOAA also received funding in the FY22 Disaster Supplemental to support work including short-range fire weather prediction, observations to support fire weather and emissions modeling and research, and weather to seasonal-to-subseasonal to climate fire weather research.

Lastly, the Joint Polar Satellite System (JPSS) and the advanced Geostationary Operational Environmental Satellite (GOES)-R series satellites host instruments capable of providing near real-time operational and long-term climate data records of many land and ocean properties related to GHG cycles, including land cover, land cover change, vegetation biophysical characteristics, wildfire information, and ocean color. In fact, NOAA provides unified and consistent multi-decadal climate data records (CDRs). CDRs are a time series of data sets generated by reprocessing data from the complete series of NOAA operational satellites (the 1970s- to the present) in a consistent, transparent, and authoritative manner. CDRs are used in industry, research, and environmental modeling. For example, the U.S. energy sector uses CDR radiation patterns over the Pacific to predict continental-scale temperature deviations up to two weeks ahead, informing early business decisions on large-scale production, transportation, and market trades. CDRs are also used in agriculture and food-security applications to assess drought extent and in developing crop yield against historical patterns to pre-positioning food relief in developing countries.

NOAA continues to be a leader and trusted partner in delivering world-class science on greenhouse gases and translating that science into actionable information. NOAA's FY23 budget requests funding for the investments needed to enable NOAA to maintain and enhance our long-term atmospheric observations, which support research on future climate scenarios. The request includes $16,100,000 in new investments to support and enhance our atmospheric observing systems, which will allow NOAA to support a Global Stocktake, an essential process of the Paris Agreement. This funding would create an independent, transparent evaluation of GHG emissions

and changes in emissions at various scales and examine the biogeochemical-climate feedbacks and the resulting climate sensitivity. It would also provide a robust understanding of the allowable cumulative GHG emissions to limit global warming at different future levels by taking into account likely changes in natural GHG sinks and sources in the ocean, land, and atmosphere. As a climate steward, NOAA partners with other federal agencies, states, local communities, tribes, territories, and private industry to expand knowledge and enable capabilities to deliver results for the American people.

4. PARTNERSHIPS WITH OTHER AGENCIES

To understand the sources of and changes occurring in GHG emissions and atmospheric levels, accurate, precise, and expansive measurements of GHGs are necessary. This work requires cooperation with numerous agencies. NOAA's frequent collaborators and friends include DOE, EPA, NIST, and NASA, among many others in this mission space.

NOAA and DOE have a long relationship of collaboration on atmospheric monitoring and measurements including leveraging DOE's Southern Great Plains (SGP) atmospheric observatory for aerosol, radiation, and GHG measurements both from the ground and from aircraft. This relationship extends to the Arctic where NOAA and DOE have a multi-decade effort of collaborating on atmospheric observations at NOAA's Barrow Observatory and many other sites across Alaska.

NOAA and the EPA have worked together on the bottom-up GHG emissions inventories by comparing inventories with direct observations of the atmosphere downwind of reported emission sources. For example, NOAA has used aircraft-based observations to identify discrepancies in bottom-up GHG emissions inventories of methane from the nation's oil and natural gas production basins and the downstream supply chain. NOAA's measurements are now part of EPA's quality assurance and verification process for the hydrofluorocarbon (HFC) estimates in the annual GHG Inventory. This innovative contribution is helping EPA and NOAA to identify areas where the estimates can be improved. NOAA also supports the integration of coastal wetlands data into the EPA-led U.S. National GHG Inventory. Through this joint effort the United States was the first country to incorporate coastal wetlands into its National GHG Inventory; now NOAA is working with EPA and the Department of State, among others, to assist other nations to include blue carbon associated with coastal wetlands in their official GHG inventories.

Over the last decade, NIST and NOAA have collaborated closely to better understand how to integrate models and atmospheric measurements in urban settings to better estimate GHG

emissions. This collaboration has consisted of information exchange, sharing of technical expertise, and modeling and tool development leading to vastly improved monitoring and understanding of GHGs emissions in urban settings.

NOAA has extensive collaborations with NASA including the development of products like the CarbonTracker described earlier. NOAA has provided critical atmospheric measurements to support several NASA experiments in the Arctic as well as those made in oil and gas regions where remote sensing technologies were being tested and compared to NOAA measurements. NOAA also played a key role in NASA's Atmospheric Tomography Mission (ATom) by providing expertise to make GHG, aerosol, and reactive gas measurements which culminated in the development of a critical dataset for evaluating satellite observations for years to come. Starting in 2023, an interagency agreement between NASA and NOAA will allow NOAA to take in-situ observations of GHGs emitted by the North American urban areas onboard a NASA research aircraft. NOAA is also planning to work with NASA on evaluating and utilizing NASA's new GeoCarb mission, which will provide the first observations of GHGs from geostationary orbit starting in 2025. These measurements will provide better daily and spatial coverage of GHG levels, and NOAA's global network will be used in the calibration of these new space-based measurements.

NOAA also participates in the Greenhouse Gas Monitoring & Measurement Interagency Working Group to coordinate on existing capabilities and opportunities for enhancing the measurement and quantification of GHG emissions and removals. Our goals include informing local to national-scale GHG emission mitigation efforts and assessing the effectiveness of GHG reduction policies over time. Coordination through this interagency working group is essential to maximize the impact of agency resources, enhance the Nation's ability to measure and monitor GHG emissions and removals and accelerate the transition of relevant research capabilities to operational use.

6. CONCLUSION

In partnership and collaboration with our Federal partners, NOAA a leader in providing global and regional observations, science, and prediction. We deliver trusted climate information, forecasts, and services to our Nation's decision-makers at all levels of government, in all U.S. regions, across geographic scales from national to local, and in all economic sectors. Underpinning NOAA's leadership in this field is our foundational GHG concentrations measurement and analysis systems that monitor and understand present trends and prepare for the future. NOAA is building on our legacy through its contribution to an integrated GHG observing system through collaborative interagency and private partnerships to meet the growing demand for accessible and accurate climate data, tools, and services that help protect the American public, economy, and natural ecosystems in the face of changing conditions.

Dr. Ariel Stein is currently ARL Director and Acting Director of the Global Monitoring Laboratory. Dr. Stein has extensive experience working with atmospheric transport, dispersion, and photochemical models. Previously, Ariel was a Supervisory Physical Scientist before becoming Acting Deputy Director of NOAA's Air Resources Laboratory. Ariel has an in-depth understanding of hybrid dispersion modeling techniques including ARL's HYSPLIT model. His research interests cover a wide range of topics dealing with atmospheric transport and dispersion modeling including the simulation of atmospheric tracer release experiments, radionuclides, smoke originated from wildfires, volcanic ash, and wind-blown dust. He has several peer-reviewed papers in these topics in prestigious international journals. He holds a B.Sc. in Chemistry from the University of Cordoba, Argentina, a M.Sc. in Environmental Pollution Control and PhD in Meteorology from Penn State University.