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I extend my deep appreciation to Chair Sherrill, Ranking Member Bice, and Members of the Subcommittee on Environment for the privilege of testifying on Working Towards Climate Equity. My name is Jeffrey Basara, and I am the Executive Associate Director of the Hydrology and Water Security Program at the University of Oklahoma and I hold the rank of Associate Professor via joint appointments in the School of Meteorology and the School of Civil Engineering and Environmental Science. Until very recently, I served as the Director of the Kessler Atmospheric and Ecological Field Station (2014-2020) and I previously served as a Research Scientist and the Director of Research for the Oklahoma Climatological Survey (OCS; the State Climate Agency of Oklahoma) from 2001 to 2018. In 2014, I was named a Kavli Fellow of the United States National Academy of Sciences and in 2019 I was a recipient of the USDA-NIFA Multistate Partnership Award and the USDA Research Education Economics (REE) Under Secretary's Award. While I am not speaking directly on behalf of the University of Oklahoma, I am testifying today in my roles as an academic researcher, administrator, teacher, and advisor on matters of science related to weather, climate, water, and ecosystems. I also wish to extend my sincere gratitude to Daniel Dziadon, Megan McKeown, Aria Kovalovich, and Dr. Kelvin Droegemeier for their input and assistance regarding preparations for this Subcomittee hearing.

The topic of climate services as related to climate equity is critically important and relevant across the spectrum of socioeconomic sectors that form the foundation of society in the United States. In my capacity within OCS, which maintains a mandate to provide weather and climate information to the various communities across the state, I saw firsthand how the collection and dissemination of weather and climate information has a tangible impact on the citizens we serve spanning all communities. This strongly influenced my professional development and has been critical in tackling challenging scientific topics in the environmental sciences that have direct and substantial impacts on society. Perhaps more importantly, it has spurred the drive to understand the end user needs and to approach science from their perspective.

Because of the impact of research projects including the Grazing CAP (sponsored by the USDA) and long term-relationships developed through the communication of weather and climate research to end users in the Great Plains, I have been able to directly engage thousands of agricultural producers in recent years through onsite and virtual workshops and events. On my end, the purpose was always two-fold: (1) education focused on the topics of drought and excessive precipitation (i.e., floods and pluvials) and (2) to share the latest science that has impacted our understanding of these topics, especially as related to the Great Plains and adjacent agricultural areas. Inevitably, my first question from the audience, regardless of time of year or location, was also along a similar theme – "What will the conditions be X months from now?". In other words, what weather and climate conditions can be expected in the foreseeable future that will impact local productivity along with overall market demand?

The Environmental Challenge

Within the environment, specific challenges that impact end users include highly variable, and violent weather such as: (1) severe thunderstorms capable of producing damaging winds, large hail, and tornadoes; (2) mesoscale and synoptic-scale excessive precipitation that exacerbates runoff and creates flooding; (3) winter storms associated with extreme snowfall, icing, and anomalously cold temperatures; and (4) landfalling tropical cyclones that produce widespread wind damage, excessive rainfall, and widespread flooding. For example, during August of 2020 a powerful complex of thunderstorms swept across the Midwest with widespread severe wind damage to structures and crops and approximately 14 million acres of corn and soybeans that were significantly impacted; the event which totaled over $11 Billion in economic losses. Additionally, the aftermath of Hurricane Harvey yielded 68 fatalities, over 300,000 structures flooded, and an estimated $120 Billion in economic losses.

Beyond the typical "weather" timescale, subseasonal to seasonal (S2S) to interannual environmental variability in precipitation and temperature can also yield significant impacts to end users. Among other S2S processes which range in temporal scale from approximately 10-90 days, two opposite hydroclimatological extremes often occur:

- *Drought* is a concern for water resource related activities given the historical frequency with which it occurs in the United States and its overall devastating impacts. Typically, drought is defined by precipitation deficits (meteorological drought) leading to soil moisture deficits (agricultural drought) followed by reduced water flow and supply (hydrological drought). Recent research analyses have also focused on the rapid intensification of drought during the growing season, or "flash drought" which can develop in 2-4 weeks. Moreover, the central United States is a climatological "hot spot" for flash drought and in 2012 flash drought developed and spread across most the central United States with overall drought-related economic costs totaling over $30 Billion. This included severe impacts to ecosystems, agriculture, and groundwater and ultimately, water shortages, navigational disruptions, effected energy systems, and reduced employment in rural areas.

- *Pluvials*, on the other hand, are represented by greater than average rainfall. While beneficial in many aspects due to the recharge of water resources and increased ecological productivity, pluvial periods are also associated with an increased number of flooding events, leading to water quality issues and changes in landscape and environment through enhanced erosion. For example, the wettest 12-month period in the United States occurred during 2019 and excessive precipitation and flooding during the growing season led to flooding and an estimated $20 Billion in economic losses.

Beyond drought and pluvial periods, additional extreme events occur including long-lasting heatwaves, extended cold snaps, and excessive winter precipitation. The United States is also prone to rapid transitions in extremes that produce weather whiplash not only in public perception, but also with direct critical physical impacts to infrastructure (including transportation, energy, etc.), water quality, and water quantity across the environmental and socioeconomic spectrum. Recent research has also shown that components of S2S variability are increasing in the United States and the transition between extreme events, including drought and pluvial periods, have been accelerating.

Individually, any of these specific extremes that span weather to climate would yield critical impacts to end users. However, coincident or compounding extreme events can produce cascading processes that lead to additional environmental extremes and impacts to end users and stakeholders. As an example of cascading events, wetter periods yield large increases in plant biomass as the ecosystem flourishes. However, when the region rapidly transitions to drought, heatwaves occur and the increased biomass dries, further increasing the fuel available for wildfires. In terms of coincident impacts, the aforementioned conditions in the Midwest had transitioned to drought during 2020 prior to the severe wind event. While generally unrelated events, the occurrence of both extreme conditions increased the overall socioeconomic impacts on end users.

The Need for Climate Services

The United States is a key global driver of weather and climate data collection via in situ observations (e.g., surface observing sites, balloon-borne observations, etc.) and remotely-sensed observations (e.g., satellite, ground-based radar, etc.). Such observations serve as the backbone for datasets used to determine the past, present, and future states of weather and climate processes from local to global scales. Additionally, the weather-climate datasets and associated applications are inherently valuable to end users across the wide spectrum of socioeconomic sectors as weather-climate processes impact the breadth of local to global society.

At the same time, within the United States alone, both the average number of billion-dollar disasters and annual economic impact/losses have quadrupled since 1980[1]. Additionally, in 2020 alone, 22 individual, billion-dollar events occurred in the United States (the most in any year since 1980 when records began) spanning hurricanes, to hailstorms, to severe weather and flooding, to drought, heatwaves, and wildfires; the total cost was approximately $95 Billion in economic losses[2].

While these large events capture the bulk of the attention, local communities and end users are often impacted in subtle ways that may also be significant and impactful. For example, considering the sector of agriculture, a late season freeze, an ill-timed heatwave, a single hailstorm, localized

[1]drought, or excessive precipitation during planting or harvest can all have dire consequences for producers. Moving forward, the risk associated with weather and climate related impacts to agriculture remains large in the United States and beyond which threatens food security and economic stability. As such akey underlying need for agricultural producers (both grazing and crops) is relevant and reliable weather and climate information.

The United States maintains a vast array of in situ and remotely sensed observations that are critical for assessing the real-time impacts of weather and climate that are directly applicable to end users, especially those within agriculture. As detailed in the National Academy of Sciences Decadal Survey for Earth Science and Applications from Space[3], the continued data collection, *and expansion*, is critical to addressing the aforementioned environmental challenges that impact stakeholders and end users from local to global scales. As such, a *critical priority* is maintained support, and expanded support, of environmental data collection efforts that inform society about the past, current, and changing state of the environment, and in particular, climate.

Additionally a variety of portals and products exist to disseminate weather-climate information to critical end users. These include (but are not limited to) federal (and federally supported) agencies via NOAA, USGS, NASA, and the USDA as well as state agencies and climate offices. In general, varying levels of coordination exist between these organizations. At the same time, each organization and entity has specific missions, focus areas, and stakeholder groups for which they primarily serve. This poses potential challenges for specific end users to identify and access climate related resources needed, especially at the local level. For example, within the agriculture sector, real-time local observations may be collected by state-level networks (e.g., mesonets) while archived observations may be a product of both state and federal efforts. Additionally most state and local communities do not have viable resources to produce forecast and projected environmental conditions (weather, S2S, and climate) and rely on federally driven efforts. In the end, gaps may develop or pathways to climate resources may be limited due to the fragmented nature of climate resources and services. This can produce climate resource inequities depending on users and stakeholders. As such, a *second priority* is to identify gaps in resources while strengthening support to the existing web of federal to state to local community connections that serve to disseminate critical climate information.

Finally, timing and trust matter. The example of agricultural producers displays a stark reality that relevant weather and climate information must meet the user needs, must be reliable, and perhaps most importantly, must be trustworthy. Otherwise, the utility of the data and information is limited. As such, a *third priority* is to further the efforts to strongly consider the needs of the end user in the utility and relevance of climate resources and to increase trust in the data, products, and resources provided.

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[1] https://cpo.noaa.gov/Who-We-Are/About-CPO

[2] https://www.climate.gov/news-features/blogs/beyond-data/2020-us-billion-dollar-weather-and-climate-disasters-historical

[3] https://www.nationalacademies.org/our-work-decadal-survey-for-earth-science-and-applications-from-space