Congressional Testimony

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before the
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"Spectrum Needs for Observations in Earth and Space Sciences"

Chairwoman Johnson, Ranking Member Lucas, and Members of the Committee, thank you for holding this hearing, and thank you for the invitation to testify today.

I am Jordan Gerth, an atmospheric scientist who holds an honorary fellowship at the University of Wisconsin-Madison Space Science and Engineering Center (SSEC). My professional service includes chairing the American Meteorological Society Committee on Radio Frequency Allocations. Established in 1965, SSEC is an internationally respected organization for the research and development of remote sensing and environmental applications. Madison, Wisconsin, is the birthplace of satellite meteorology, in large part due to the work of the late Dr. Verner Suomi, a professor that developed the spin-scan cloud camera to provide the first animations of weather patterns in the 1960s.

In holding this hearing today, you implicitly recognize the importance of radio frequencies for Earth and space science applications. There are a growing number of important issues related to spectrum sharing with 5G wireless communications, both for the atmospheric and oceanic sciences and radio astronomy, and also related to the transmission and collection of weather information. My testimony today will focus particularly on the criticality of protecting the clarity of Earth-emitted radio frequencies to maintain the quality and public confidence in weather warnings and forecasts and the need for transparent processes to facilitate that objective.

Importance of sustaining passive microwave sensing for weather forecast accuracy

Basis for microwave sensing. While the accuracy of weather forecasts is popular fodder as a conversation starter among Americans, the reality is that weather forecasts have never been more accurate in history. Weather forecasts for the contiguous United States are particularly accurate. The seven-day forecast today is as accurate as the five-day forecast was 20 years ago. The most important aspect of making the right forecast is taking the right observations and using them effectively. That is where the nexus between radio frequencies and weather forecast lies.

While visible or infrared satellite imagery as shown on the evening television news weather report partially contributes to the quality of weather forecasts, the most valuable frequencies are microwaves, particularly those between 20 and 200 GHz. It likely comes as a surprise to many that the Earth's atmosphere emits microwaves, but they are naturally occurring and not harmful to us.

Molecules such as oxygen and water vapor emit microwaves at unique frequencies, and those emissions help meteorologists identify and characterize weather systems and develop a vertical profile of temperature and humidity without releasing a weather balloon. Microwaves are additionally useful for weather analysis because they typically traverse through clouds without absorption and thus enabling meteorologists to examine the internal structure of storms in determining whether strengthening or weakening is likely.

Current instrument for microwave sensing. Given the benefits of microwaves, satellites have been designed to sense them for over 40 years. The most recent NOAA instrument to sense atmospheric microwaves is the Advanced Technology Microwave Sounder, or ATMS. The ATMS is considered a passive sensor because it is "listening" to the atmosphere. This is unlike a radar which itself emits a pulse and then "listens" for the return.

As soon as next year, NOAA will launch its third satellite, the second in the Joint Polar Satellite System (JPSS), with an ATMS instrument[1]. As each JPSS satellite orbits the poles every 100

[1] Instrument: ATMS, https://space.oscar.wmo.int/instruments/view/atms (accessed on 17 July 2021)

minutes from 500 miles above the surface of Earth, ATMS collects 22 distinct observations of the atmosphere every 10 to 50 miles within a 1,370-mile swath. A single JPSS satellite observes every location on Earth at least twice daily. Of those 22 observations, ATMS is designed to sense at 23.8 GHz, among other frequencies, to collect information about water vapor. 23.8 GHz is sensitive to concentrations of water vapor near the ground and when used in combination with other frequencies can contribute to a vertical profile, or distribution, of humidity at various heights above the ground. This is useful information for precipitation forecasts.

Numerical weather prediction. The importance of JPSS and other weather satellites that NOAA, NASA, and other nations operate in providing observations for weather forecasts created with supercomputers cannot be understated. Approximately 99% of weather observations that supercomputers receive originate from satellites, and after quality control, approximately 90% of observations assimilated, or integrated, using complex algorithms into computer weather models are from satellites[2].

The collection of complex algorithms is known as a numerical weather prediction model because the model converts observations into a numerical representation of the atmosphere and then advances it forward in time. At its core, weather forecasting is an initial-value math problem. Thus, if observations do not provide a complete assessment of the atmosphere, then weather forecasts will be less reliable and less accurate over time.

Improvements in numerical weather prediction performance over the past 20 years can be attributed to satellite observations, especially microwave sensing of water vapor,[3] such as at 23.8 GHz and other frequencies. Today, approximately 15 to 30% of the assimilated observations are from passive microwave sensing[4]. A 2020 study from Europe found that microwave sensors led

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[2] Fact sheet: ECMWF's use of satellite observations, https://www.ecmwf.int/en/about/media-centre/focus/2020/fact-sheet-ecmwfs-use-satellite-observations (accessed on 17 July 2021)
[3] Geer, A. J., F. Baordo, N. Bormann, P. Chambon, S. J. English, M. Kazumori, H. Lawrence, P. Lean, K. Lonitz, and C. Lupu. "The Growing Impact of Satellite Observations Sensitive to Humidity, Cloud and Precipitation." *Quarterly Journal of the Royal Meteorological Society* 143, no. 709 (October 2017): 3189–3206. https://doi.org/10.1002/qj.3172.
[4] Liu, Quanhua (Mark), Changyong Cao, Christopher Grassotti, and Yong-Keun Lee. "How Can Microwave Observations at 23.8 GHz Help in Acquiring Water Vapor in the Atmosphere over Land?" *Remote Sensing* 13, no. 3 (January 30, 2021): 489. https://doi.org/10.3390/rs13030489.

to forecasts that were "very significantly improved at short lead times, 12 to 24 hours," and also beneficial but, to a lesser extent, out to four days in the Northern Hemisphere[5]. These observations are approximately twice as valuable in reducing model errors out to six days as the three next most valuable observation types individually, including hyperspectral infrared radiances, radiosondes, and radio occultations[6].

Microwave sensing harm from 5G. Terrestrial radio systems that emit 5G signals too closely to defined bands for weather sensing are a formidable threat to weather forecast and warning services because they are much louder than the atmosphere that satellites are trying to observe. Harmful interference is likely because if the 5G signal is so loud that it is obvious, it will easily mask the atmospheric emission such that it is irrecoverable. Even if the 5G signal does not overpower the atmospheric emission completely, it will still be extremely difficult, if not impossible, to separate the contribution of the atmosphere from the 5G signal with current assets. Because the satellite sensors are only "listening", there are no good options to mitigate this interference.

To state it clearly: If there is no observation of a portion of the atmosphere because of 5G signal interference there, it cannot be the basis for a weather analysis and global and local forecasts may suffer alike, leading to a loss of lead time for storms. Using a 5G-inflated observation could lead to a worse forecast unless numerical weather models are configured to use microwave observations with a decreased confidence in their quality, a mitigation that would have far-reaching complications for weather forecasts beyond where there is interference.

Policy options for protecting spectrum for science applications through improved processes

A growing challenge. Spectrum allocation issues have been a growing concern for the weather enterprise beyond the Federal Government. Previously, NOAA and NASA worked behind the scenes to resolve issues with limited if any contributions from academic and industry partners.

[5] Duncan, David, and Niels Bormann. "On the Addition of Microwave Sounders and NWP Skill, Including Assessment of FY-3D Sounders." *EUMETSAT/ECMWF Fellowship Programme Research Report*, 2020. https://www.ecmwf.int/node/19760.
[6] Saunders, Roger. "The Use of Satellite Data in Numerical Weather Prediction." *Weather* 76, no. 3 (March 28, 2021): 95–97. https://doi.org/10.1002/wea.3913.

However, as the appetite for more wireless spectrum has increased, more scrutiny of each proposal is necessary. At a minimum, NOAA and NASA should share their studies publicly and expediently, something that was missing for 24 GHz in 2019.

When the FCC issues a new notice of proposed rulemaking for 5G services, there are two separate questions that should be addressed:

1. Will this rulemaking proposal lead to interference with satellite sensors?
2. If it does, to what degree will that interference lead to a degradation in the accuracy of weather forecasts?

Collectively, the answers to these two questions can inform the best course of action for spectrum sharing, and tough decisions may need to be made. However, the answers to these questions are not straightforward, take substantial time to address, and the best way to answer them is with better coordination and cooperation between the FCC, NTIA, NOAA, and NASA and in a manner that is transparent. In particular, the second question is most challenging to answer because to depends substantially on the deployment strategy of the new 5G network.

Actively valuing spectrum for weather prediction. As part of the Weather Research and Forecasting Innovation Act of 2017[7], NOAA is required to conduct an Observing System Simulation Experiment (OSSE) before buying or leasing a new weather satellite or new weather satellite data set that costs at least $500 million. This directive could be expanded, potentially using spectrum auction revenues. NOAA, NASA, and other agencies that operate satellites for environmental sensing should regularly audit the use of spectrum and recent, peer-reviewed studies from federal and federally supported scientists, such as those at NOAA Cooperative Institutes, should reflect the application and value of each radio frequency sensed, in terms of contribution to numerical weather prediction skill through a data denial experiment or otherwise.

This valuation should be conducted routinely because the speed of peer review is much slower than FCC proceedings. FCC proceedings have timelines of 60 to 90 days for comment while

[7] H.R.353 – Weather Research and Forecasting Innovation Act of 2017, https://www.congress.gov/bill/115th-congress/house-bill/353 (accessed on 17 July 2021)

funding research for peer review related to a new proceeding is likely to take 18 to 24 months at a minimum. A new satellite currently takes 5 to 10 years to build and launch, and those program costs are in the billions per satellite. The estimated total cost of the JPSS program from 1995 through 2038 is $18.8 billion[8], so a loss of sensing capability that diminishes its intended mission has a real tangible cost for taxpayers even without considering the economic loss from the reduction in weather predictability.

Integrating science into transparent decision-making. In light of the GAO findings and recommendations, I am left wondering what recourse NOAA, NASA, or another government agency has if the FCC and/or the Department of State does not allay their raised concerns about shared spectrum rulemaking proposals. Chairwoman Johnson and Ranking Member Lucas were rightfully concerned about the potential of weather forecast degradation in calling for the GAO to investigate the governmental processes that have led us to this point. Yet, as a scientist, it is discomforting that the FCC can conduct rulemaking without studies that could have an impact on another agency to accomplish its Congressionally directed mission.

This Committee should consider whether oversight or involvement from the Office of Science and Technology Policy (OSTP), federal advisory committees, or other mechanisms that, at a minimum, conduct and make publicly available all relevant scientific studies prior to a rulemaking decision, may facilitate a process with more integrity for all stakeholders. While I understand that the FCC does not fall under this Committee's jurisdiction, legislative remedies that require proactive and closer cooperation on the sharing of Earth exploration-satellite service-allocated spectrum between the FCC, NTIA, NOAA, and/or NASA specifically may also be necessary. Policy priorities for expanding 5G with sustaining the quality of weather forecasts must be balanced.

Working together. Despite the importance of maintaining the accuracy of weather forecasts, the weather enterprise is not a competitor of the telecommunications industry, and we should not characterize this issue as one of us versus them. The telecommunications industry is an essential partner is delivering urgent weather messages to cell phones and establishing communications

[8] Joint Polar Satellite System FAQ, https://www.jpss.noaa.gov/faq.html (accessed on 17 July 2021)

immediately after a disaster to assist in the response. I truly believe that with a better understanding of how satellite sensors collect weather information and how those observations improve weather forecasts that industry partners can work with us to deploy equipment outside of pre-existing bands for Earth sensing.

<u>The future of spectrum allocations and weather satellite observations</u>

In our national conversations about 5G, we are forward-looking into how technology will evolve the economy, expand opportunities, connect Americans, and improve society. We should apply the same mindset to weather prediction and satellite observations. The accuracy of weather forecasts improves by one day every decade, and this is a trend that we can continue with sustained investments into NOAA and NASA satellite programs and exploring options to partner with the expanding space enterprise.

On the horizon, the capability of small satellites and cube 'sats' is increasingly promising to enhance the temporal frequency of passive microwave sensing, though they are not yet a proven replacement for flagship missions like JPSS. In the coming decades, there is the prospect of microwave sensing from the geostationary orbit, approximately 22,500 miles above the surface of Earth, to provide continuous monitoring of the internal dynamics of hurricanes over our adjacent oceans for the first time. Though not imminent solutions, both innovations would benefit from protected allocations for Earth exploration-satellite service (EESS) at microwave frequencies and increase weather predictability.

Finally, the United States has been a leader in weather satellite observations that now extends back 60 years, a history that began in Wisconsin. We should continue our national leadership in demonstrating stewardship of our spectrum resources for science applications and particularly weather sensing. Pushing the frontiers of weather forecasting out to and beyond 10 days will depend not only on our domestic spectrum policy but also our current and future ability to conduct passive microwave sensing over the remainder of North America, our adjacent oceans, and other continents, particularly Asia and Oceania. The United States should advocate at future World Radiocommunication Conferences (WRC) accordingly.

While the contentious circumstances surrounding 24 GHz were far from desirable, and 23.8 GHz sensing contributes useful water vapor information for weather forecasting that we may partially lose, the longest heritage of microwave sensing is between 50 and 60 GHz, where there are 13 ATMS bands[9]. We should be especially careful of sharing arrangements in and around 50 to 60 GHz or the consequences for weather prediction may be more dire.

Summary

Thank you for holding this hearing and allowing me to explain the science that underlies the importance of passive microwave sensing for weather forecasting and how processes that require scientific input can benefit from increased transparency. Despite its complexity, establishing a process that enhances decision-making for certain spectrum allocations with science applications will benefit all parties and the American public. I appreciate your support in increasing confidence in our nation's weather warnings and forecasts and maximizing the value of the United States investment in weather sensing from space.

[9] STAR JPSS – Instruments – Advanced Technology Microwave Sounder (ATMS), https://www.star.nesdis.noaa.gov/jpss/ATMS.php (accessed on 17 July 2021)

Acronyms

ATMS	Advanced Technology Microwave Sounder
EESS	Earth exploration-satellite service
FCC	Federal Communications Commission
GAO	Government Accountability Office
JPSS	Joint Polar Satellite System
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NTIA	National Telecommunications and Information Administration
OSSE	Observing System Simulation Experiment
OSTP	Office of Science and Technology Policy
SSEC	Space Science and Engineering Center, part of UW-Madison
WRC	World Radiocommunication Conference