

# Opportunities and Challenges for AI in NOAA's Weather and Climate Mission

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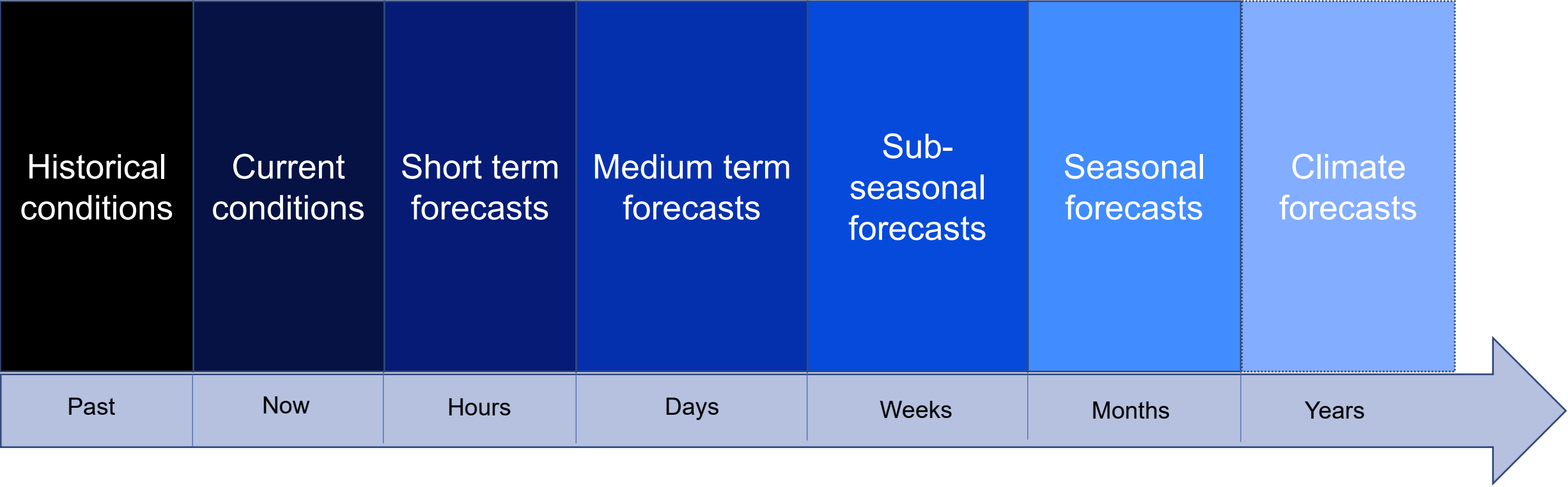
77th Meeting of the NOAA Science Advisory Board

Panel on Artificial Intelligence

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**The**   
**Weather**  
**Company**  
An IBM Business

# Environmental Data Across Timescales



**Lead Time**

# The Weather Content Value Chain



Satellite  
 Radar  
 Weather Stations  
 Balloon soundings  
 Lightning  
 ...  
 Aircraft  
 Smartphones

GFS  
 GEFS  
 NAM  
 HRRR  
 ECMWF  
 ...  
 Private sector  
 models

Routine weather  
 Severe & Extreme  
 weather  
 Aviation forecasts  
 ...

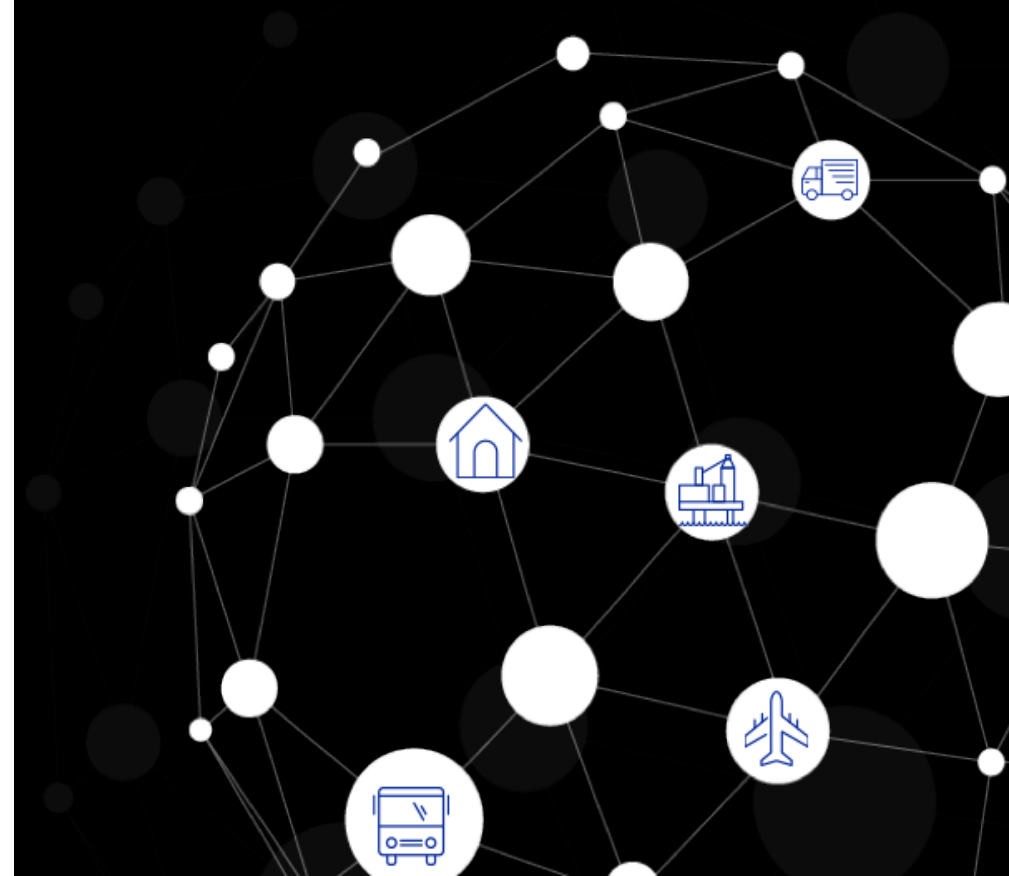
Flooding  
 Flight Delays  
 Electric Demand  
 Traffic Flow  
 Retail Activity  
 Insurance Risks

Evacuate  
 Cancel Flights  
 Buy Reserves  
 Leave Early  
 Stock Shelves  
 Sell Reinsurance



# Observations

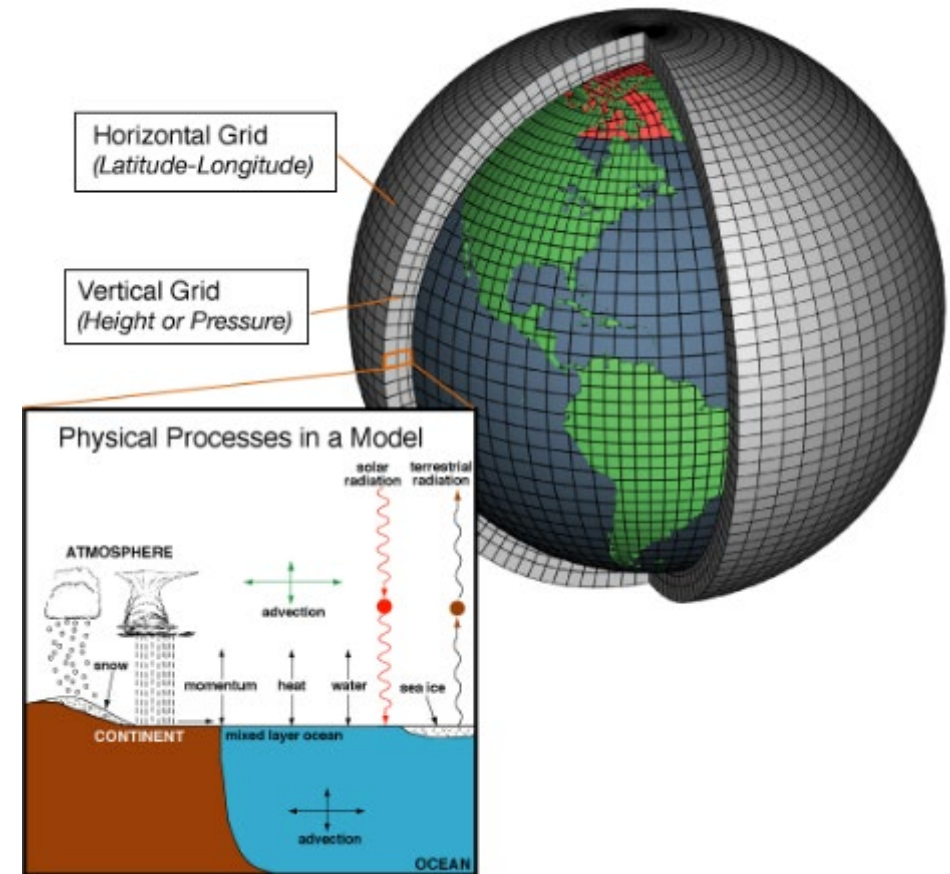
- AI enables translation, calibration, quality control, assimilation at scale
  - More sources (satellites, remote sensing)
  - New sources (smartphone pressures, connected vehicles, signal attenuation)
  - Inferred from non-meteorological information (e.g. traffic flow)
  - Low signal, high noise, high volume



# Numerical Weather Prediction (NWP)

NWP models simulate the atmosphere via physical equations and parameterizations from a starting state derived from observations.

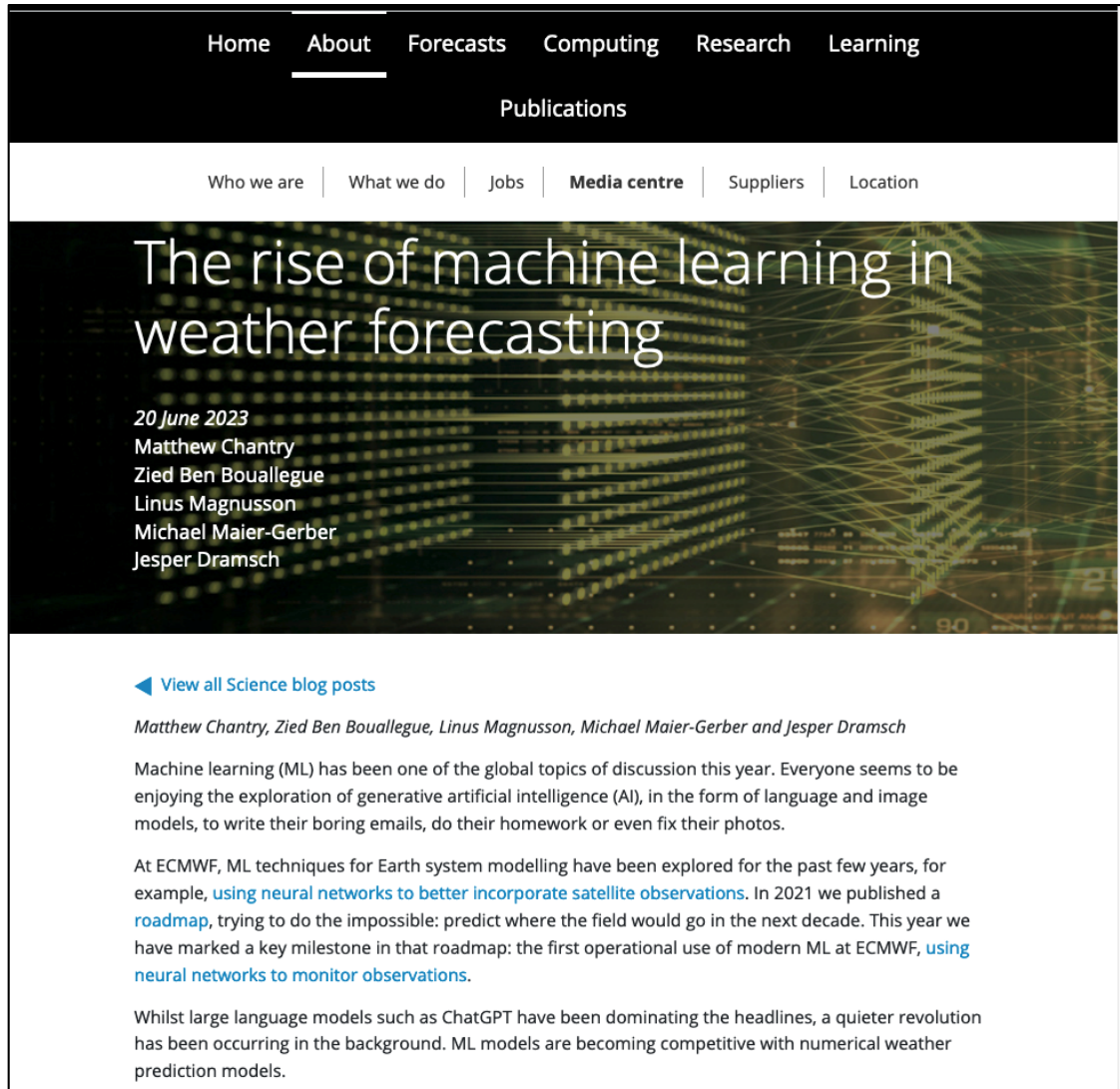
- Forecast errors arise from imperfect NWP models and initial conditions + chaos
- **BUT**
  - Historical data allows correcting and/or quantifying systematic NWP model errors
  - Combining many diverse NWP model forecasts helps characterize possible *situationally dependent* weather possibilities
  - Calibration makes the forecast probabilistically accurate (reliable) + sharp (informative).



Source: US National Oceanographic and Atmospheric Administration



# An AI Revolution in NWP is Underway!



The screenshot shows the top navigation bar of the ECMWF website with links for Home, About, Forecasts, Computing, Research, and Learning. Below this is a 'Publications' section with sub-links for Who we are, What we do, Jobs, Media centre, Suppliers, and Location. The main content area features the title 'The rise of machine learning in weather forecasting' with a date of 20 June 2023 and authors: Matthew Chantry, Zied Ben Bouallegue, Linus Magnusson, Michael Maier-Gerber, and Jesper Dramsch. A 'View all Science blog posts' link is visible. The text of the article discusses the use of machine learning in weather forecasting, mentioning neural networks and satellite observations.

<https://www.ecmwf.int/en/about/media-centre/science-blog/2023/rise-machine-learning-weather-forecasting>

“Whilst large language models such as ChatGPT have been dominating the headlines, a quieter revolution has been occurring in the background. ML models are becoming competitive with numerical weather prediction models.”

- Chantry et al., in a recent ECMWF Blog

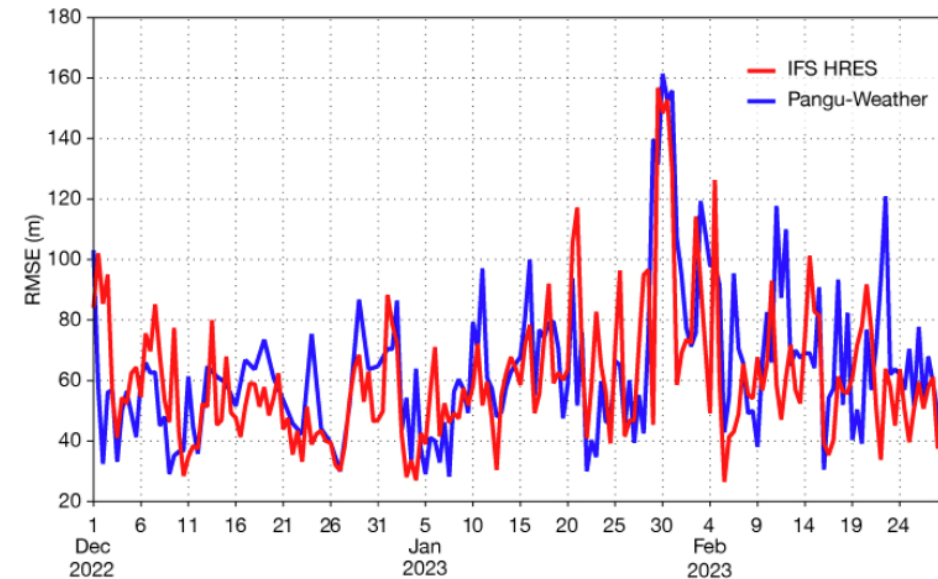
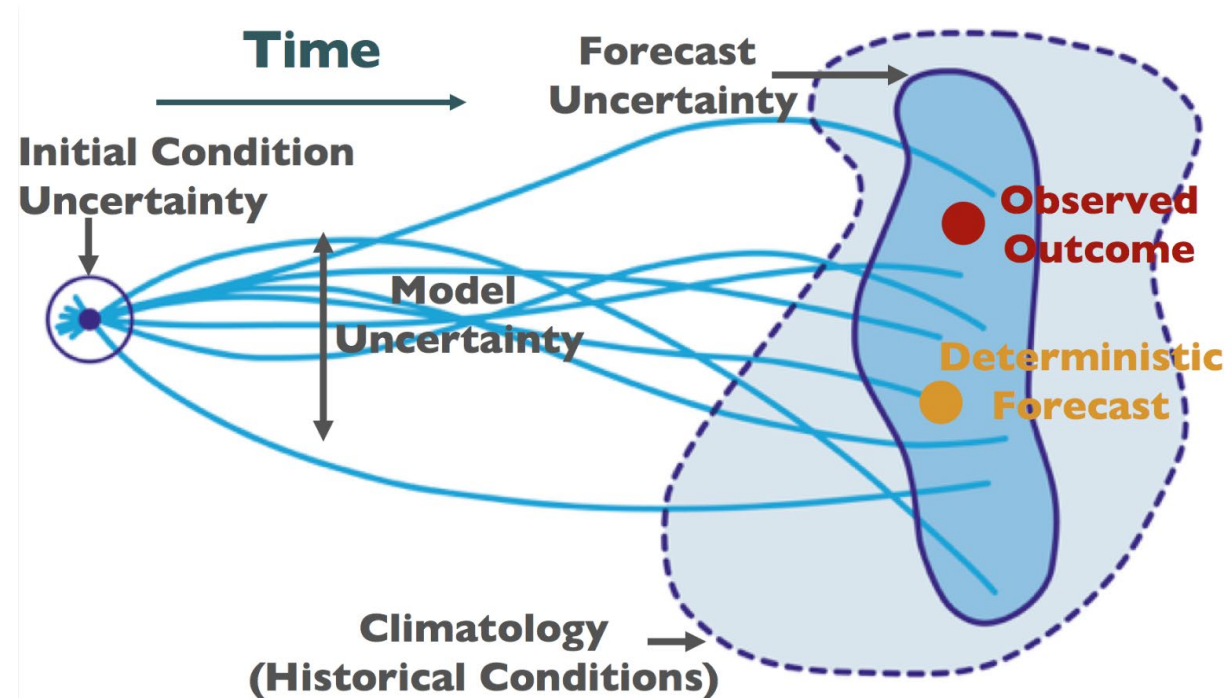


Figure 1: Root mean square error (RMSE) scores of 500 hPa geopotential height for IFS high-resolution forecasts (HRES) and Pangu-Weather over Europe for winter 2022/23 at day 6, measured against operational analysis. Pangu-Weather and the IFS produce comparably accurate forecasts and share a forecast “bust” near the end of January.

# AI-NWP Opportunities

- Improved forecast accuracy
- Simplified model deployment
- Faster processing on simpler hardware
- Large ensembles to better quantify uncertainty
  - Calibrated ensembles coupled with impact and optimization models enable better decisions!
- Climate model downscaling



# Forecasts and Nowcasts

## Creation

- AI can help forecasters produce products faster and more accurately
  - Better initial post-processed guidance
  - Automation of standard products
  - Focus attention on most important tasks

## Communication

- Large Language Models (LLMs) can provide customized, relevant data to the public
  - Timely displays and alerts
  - Interactive chats
- BUT they are prone to "hallucination"
- Generative AI could be used to sow disinformation and create public confusion.

The screenshot shows a Mastodon post from the account 'WiredPen' (Digital musings from @kegill). The post is categorized under 'TECH & SOCIETY' and is titled 'ChatGPT: hallucinations about weather data'. It was written by Kathy Gill on April 1, 2023, and has no comments. The post content is as follows:

**What was the total rainfall in Seattle in 2010? What was the average for the state of Washington?**

**NOAA**

- **WA state rainfall for 2010: 47.32"**  
**1900-2000 mean: 42.03"**
- **Seattle rainfall for 2010: 47.04"**

**chatGPT**

- **WA state rainfall for 2010: 36.24"**
- **Seattle rainfall for 2010: 37.49"**

NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Mapping, published March 2023, accessed April 2, 2023 from <https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/mapping/45/pcp/201012/12/value>  
<https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/city/mapping/45/pcp/201012/12/value>

K.Gill, private communication with OpenAI's chatGPT, March 31 and April 1, 2023



# Impact Translation

- Public safety messages
- Business operations
- Partnering with industry



Supply chain optimization



Customer engagement



Store operations



Risk & financial management



Safety & operations



Situational awareness



Outage prediction



Crop yield

“When a good idea is born, or when the first prototype of an invention is created, we should celebrate its potential to change the world. But progress is as much about implementation as it is about invention.”

- Derek Thompson, 2023: “Why the age of American progress ended.”  
*The Atlantic.*

# AI Adoption Challenges

“AI activities are growing rapidly within atmospheric sciences, and the NWS is part of this growth. However, **the activity is fragmented and lacks the needed infrastructure** for improved coordination of effort. Current obstacles to progress include **insufficient workforce training in AI/ML, a lack of curated datasets and software** that can be used for development and evaluation of these approaches, **the absence of a centralized clearing house** available to NWS personnel for **technical expertise** and consultation, **limited operational compute resources**, and **a lack of a clear end-to-end project pathway that encompasses exploration, development, testbed/proving ground and operational implementation.**”

- Roebber and Smith, 2023



Prospects for Machine Learning Activity within the United States National Weather Service

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**Early Online Release:** This preliminary version has been accepted for publication in *Bulletin of the American Meteorological Society*, may be fully cited, and has been assigned DOI 10.1175/BAMS-D-22-0181.1. The final typeset copyedited article will replace the EOR at the above DOI when it is published.

# NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography (AI2ES)

AI2ES is developing *novel, physically based* AI techniques that are demonstrated to be *trustworthy*, and will directly improve *prediction, understanding, and communication* of high-impact weather and climate hazards, improving climate resiliency.



[ai2es.org](https://ai2es.org)



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[ai2es.org](https://ai2es.org)

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