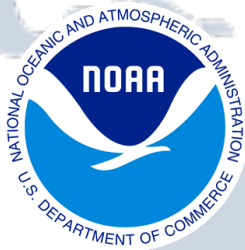


NOAA's National Climatic Data Center

Progress and Prospects of the Scientific Priorities for Climate-Related Observations, Data, and Analysis



Thomas R. Karl, L.H.D.

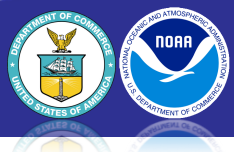
Director, NOAA's National Climatic Data Center
Chair, U.S. Subcommittee on Global Change Research

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Protecting the past... Revealing the future

Overview

- Key issues highlighted from the perspective of observed changes in the climate system
- Based on this perspective a few observations are made about future priorities related to understanding and documenting climate-related changes.



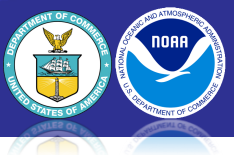
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Evolution of Career

Scientific priorities have been strongly influenced by new observing and data systems

- 1970s— Global temperature estimates land only and primarily northern hemisphere annual average
- 1980s— First attempts at constructing a truly global mean temperature index, but driven largely by subjective assessments of data biases

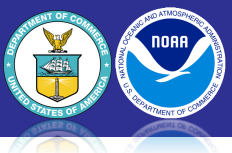


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Evolution of Career

- 1990s— Objective methods for assessing time-dependent biases of global temperatures
- Maximum and minimum temperatures
 - Data Rescue projects provide much more data
 - Paleoclimate data enable hemispheric assessment of long-term changes by year
 - Global Climate Observing System and the concept of Essential Climate Variables
 - IPCC and National Climate Assessments require integration of diverse datasets

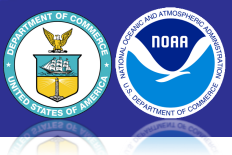


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Evolution of Career

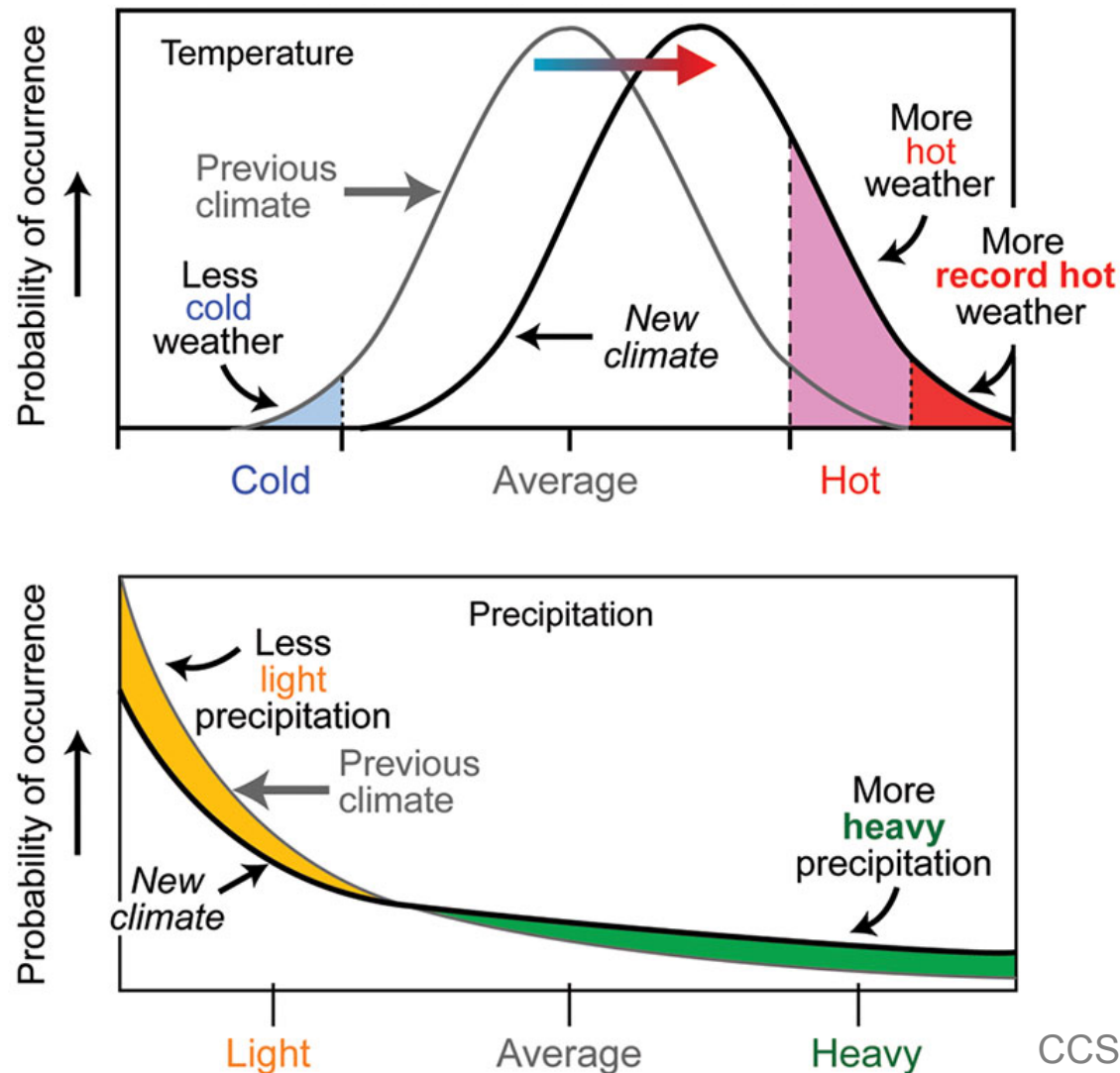
- 21st Century— Maturation of “Climate Data Records” e.g., version control, R2O, reproducibility, transparency, scientific data stewardship
 - Daily and high resolution data becomes much more readily available
 - Understanding extreme events becomes a key scientific priority e.g., BAMS special annual report on Attribution
 - State of the Climate Annual Report (250 authors, 60 countries)
 - Reanalysis becomes commonly available enabling considerable insight into changes in important weather and climate phenomena
 - Fully objective satellite-derived and in-situ datasets become available
 - Hurricane intensity
 - Precipitation extremes
 - Sea level
 - Global monthly monitoring including droughts



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Ability to Explore Changes in the Probability of Extremes



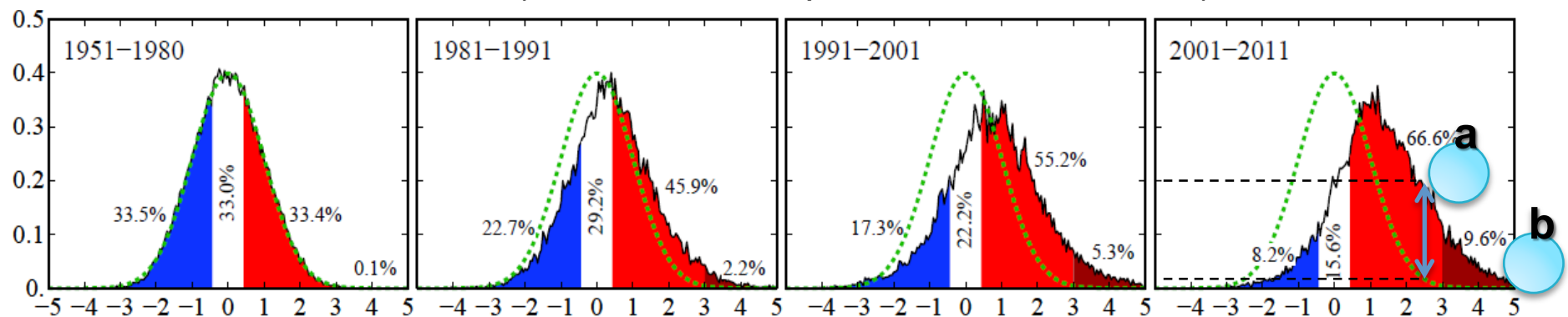
CCSP SAP 3.3, 2008

Monthly Global Temperature Data

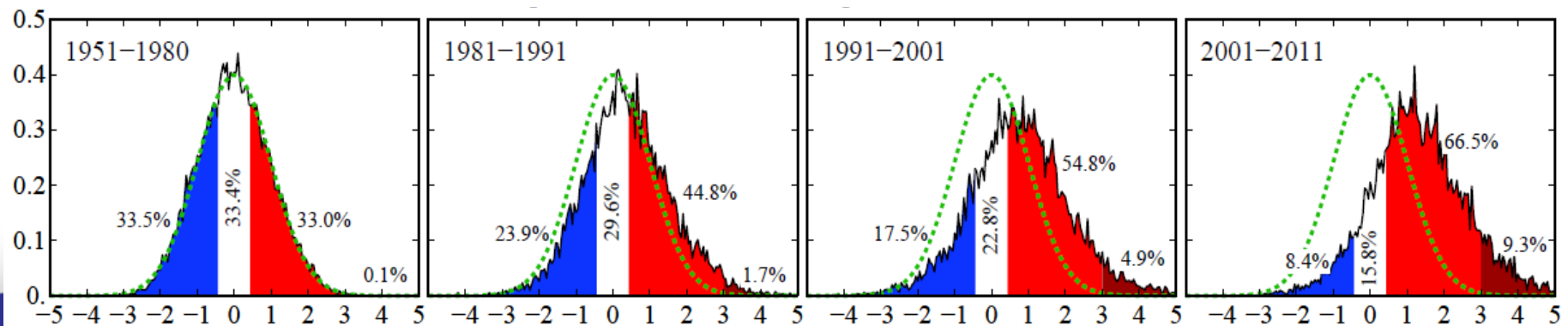
- 2001-2011 compared to 1951-80
 - Doubled likelihood of a hot month (red shading) compared to 1951-80 (a)
 - Almost 10% chance of what used to be a 1 in 1000 year event (1951-80) (b)

Based on Hansen, J. et al., 2012

All Stations (Northern Hemisphere Land – Summer)



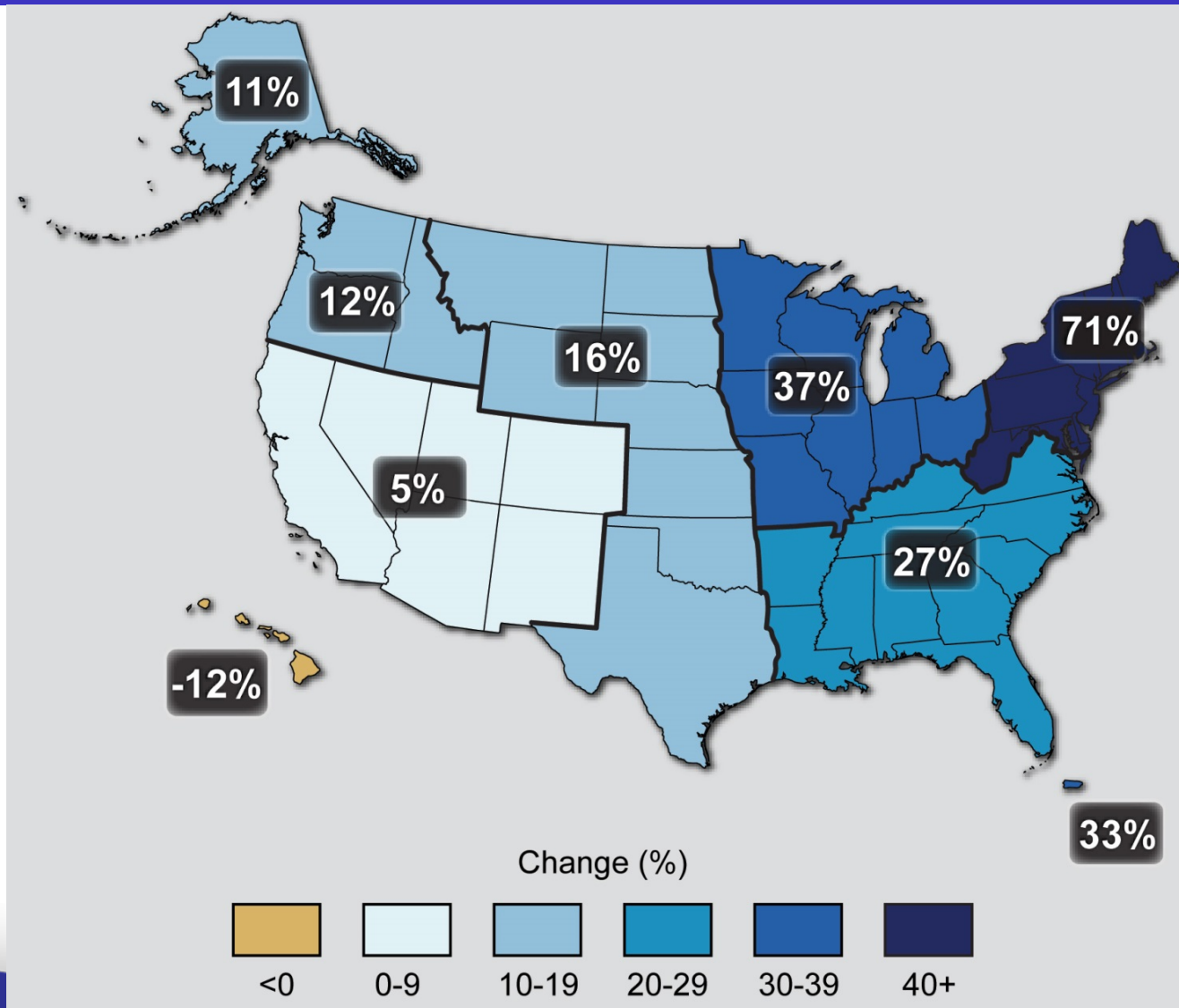
Limited Stations (Northern Hemisphere Land – Summer)



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Heaviest 1% during 1958 - 2012



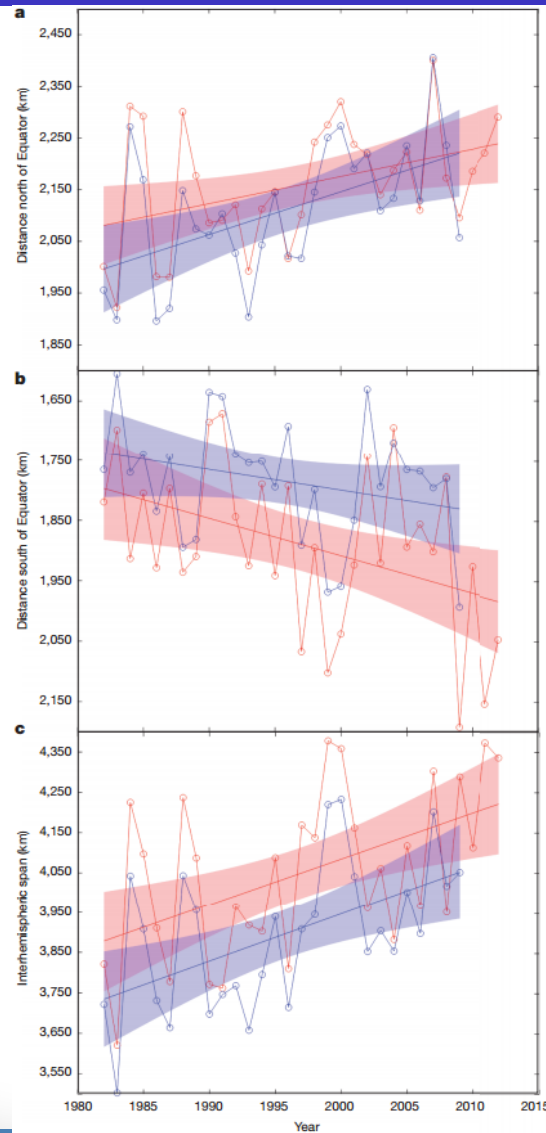
updated from Karl
et al. 2009

Poleward Migration of Hurricane Tracks

Northern Hemisphere

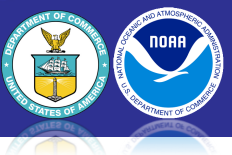
Southern Hemisphere

Difference



Red = best track data
Blue = HURSAT reanalysis

Kossin, Emanuel and Vecchi,
Nature 2014

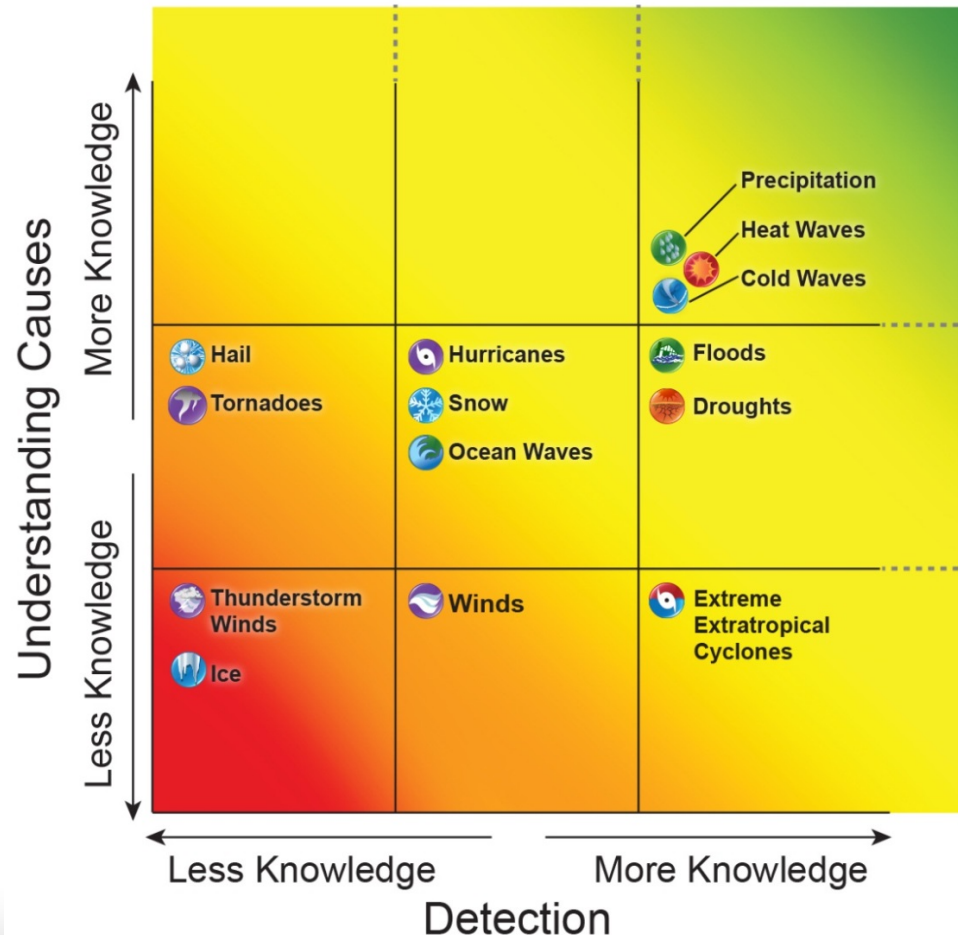


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Current State of Scientific Knowledge

Adequacy for Detection and Understanding Causes of Changes for Classes of Extremes



Series of four workshops/papers for the Bulletin of the American Meteorological Society (BAMS)

- **Monitoring and Understanding Changes in Extreme Storm Statistics: State of Knowledge.** Kunkel, K.E. et al., 2012, BAMS
- **Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods and Droughts in the United States: State of Knowledge.** Peterson, T.C. et al., 2013, BAMS
- **Monitoring and Understanding Changes in Extreme Winds, Waves, and Extratropical Storms along the Coasts: State of Knowledge.** Vose, R.S. et al., 2014, BAMS
- **CMIP5 Climate Model Analyses: Climate Extremes in the United States.** Wuebbles, D., et al., 2014, BAMS

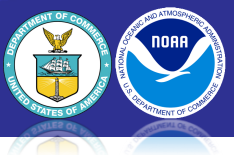
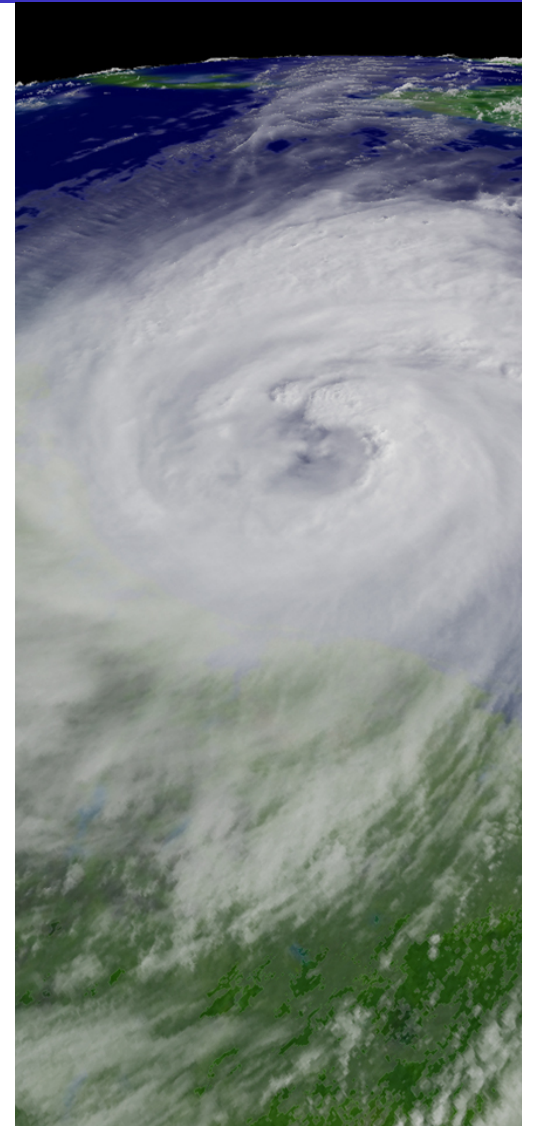


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Evolution of Career

- Sub-daily data becoming more relevant and prevalent
 - Hourly data for extremes
 - Clausius–Clapeyron relationships at varying time and space scales as related to precipitation extremes
 - Non-normality of temperature extremes and its implications



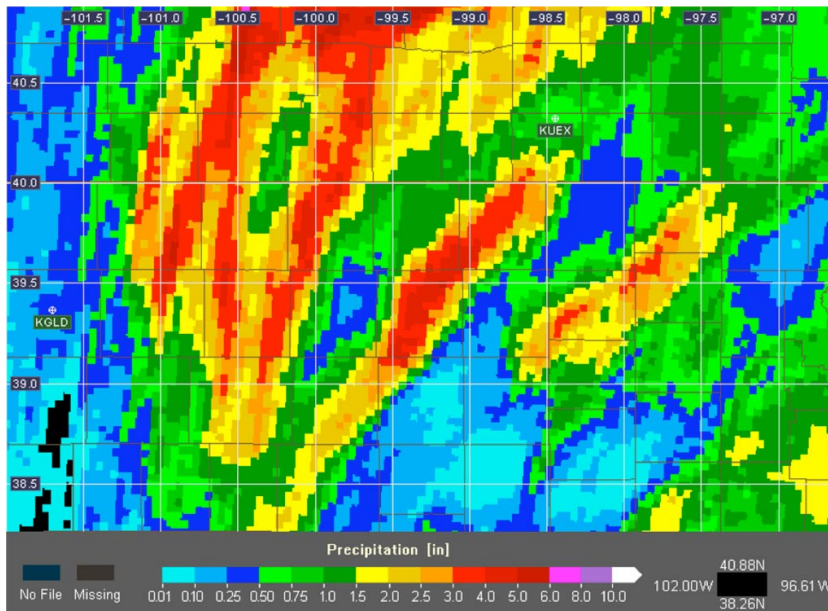
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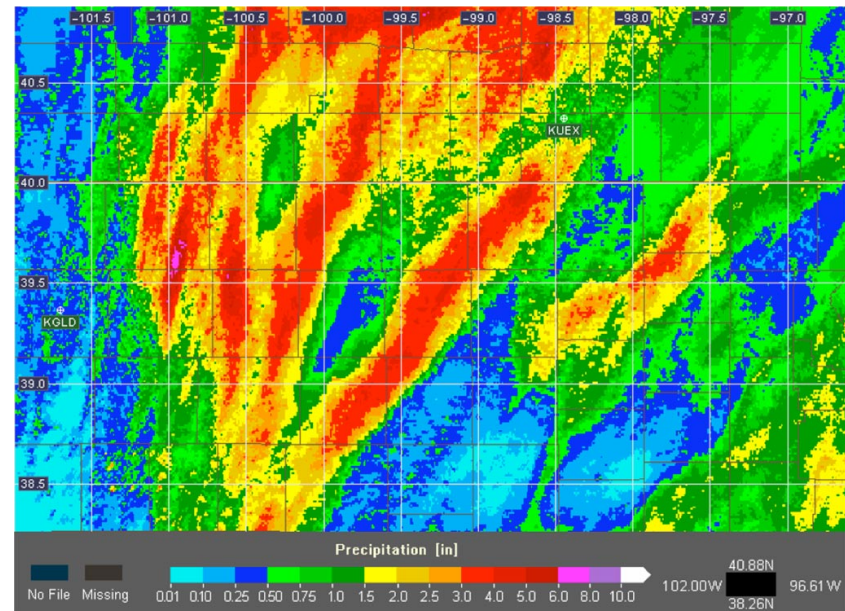
Reprocessing Radar Data

Thunderstorm from 5/24/2008 over Northwest Kansas

Original



Corrected, Reprocessed

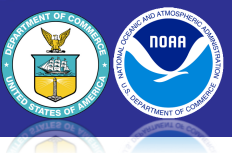


- Higher spatial and temporal resolution (1 km, 5 minutes), reduction of artifacts and problems introduced in operational processing
- Much higher volume of data. Limited by I/O versus computational speed.

Evolution of Career

Key factors, discoveries, and influences

- WMO
- IPCC (all of the physical climate assessments)
- U.S. National Climate Assessment (all three)
- Synthesis and Assessment Products (extremes and tropospheric temperatures)
- GCOS and UNFCCC (SBSTA)
- USGCRP
- AGCI (extremes workshop)
- Chair of USGCRP
- Failed attempt to execute a NOAA Climate Service



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Evolution of Global Change Research

- Big data has enabled improved datasets and analysis
- The impact of extreme weather and climate events has inspired far more requirements for data, information, and analysis of predictive capability than the community has been able to deliver
- Expectations with respect to downscaling information (both space and time) has exceeded our ability to deliver



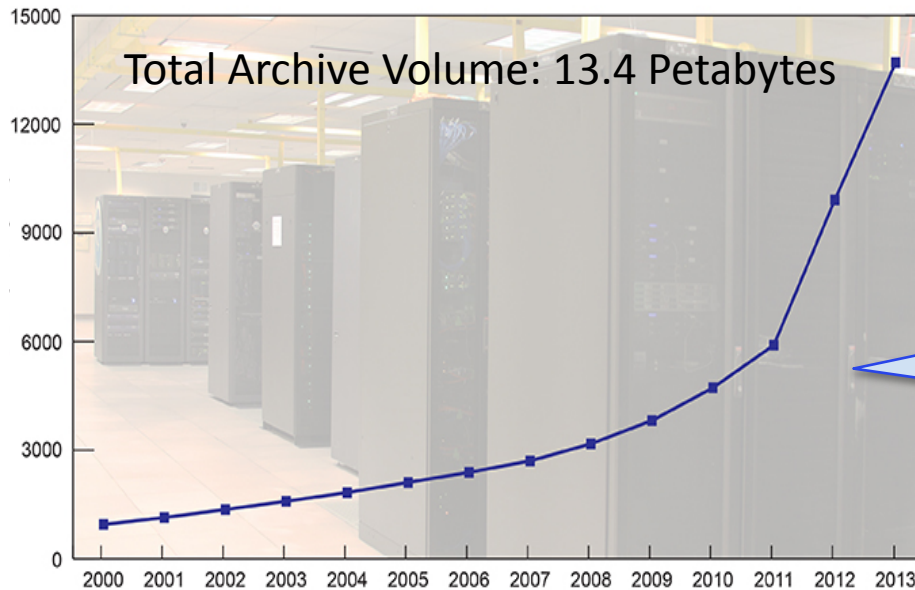
U.S. Navy photo by Chief Mass communication Specialist Ryan J. Courtade



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Archive and Access

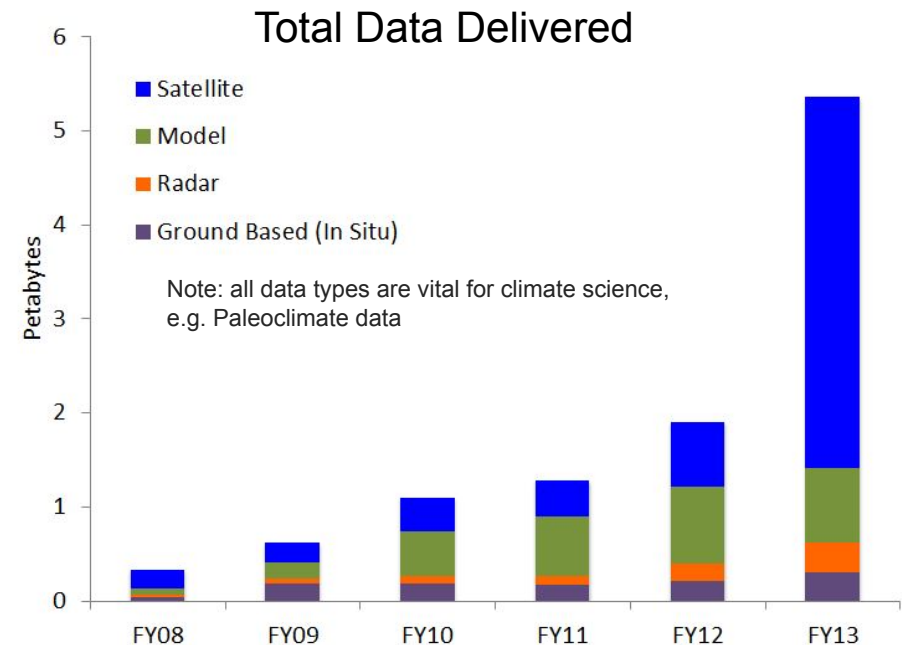


Users download ~5 PB per year
 = 5 Billion Kindle Fire e-Books/year
 = 2,300 Kindle Fire e-Readers/day

Amazon
Kindle Fire



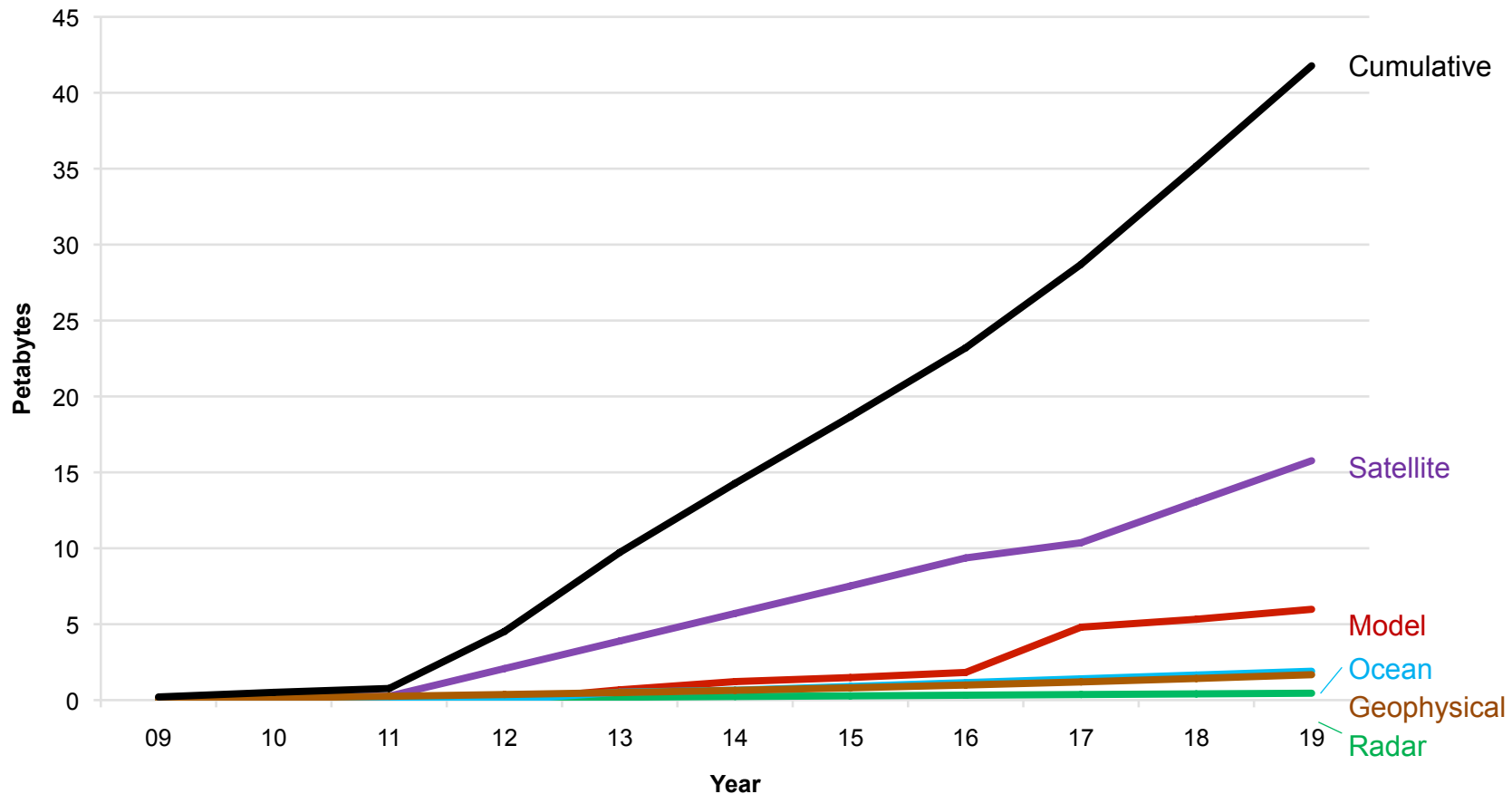
NCDC provides safe storage of 13.4 PB
 = 13.4 Billion Kindle Fire e-Books
 = 2.2 Million Kindle Fire e-Readers



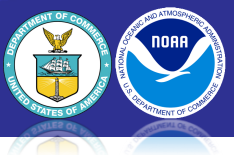
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Data Growth



By 2019, NOAA will hold over 40 Petabytes of environmental data, even with compression.



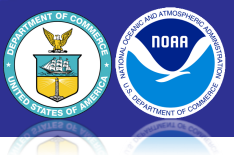
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Global Change Research

What has enabled progress, and what has slowed it?

- Cheaper data storage and improved capabilities for data sharing (Earth System Grid, Global Change Information System, NOMADS, etc.)
- Cloud solutions emerging and have potential
 - Reprocessed all AVHRR SSTs in one day using Cloud versus a few years in the 1990s
- Difficulty in connecting across disciplines and institutions

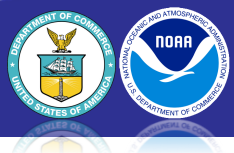
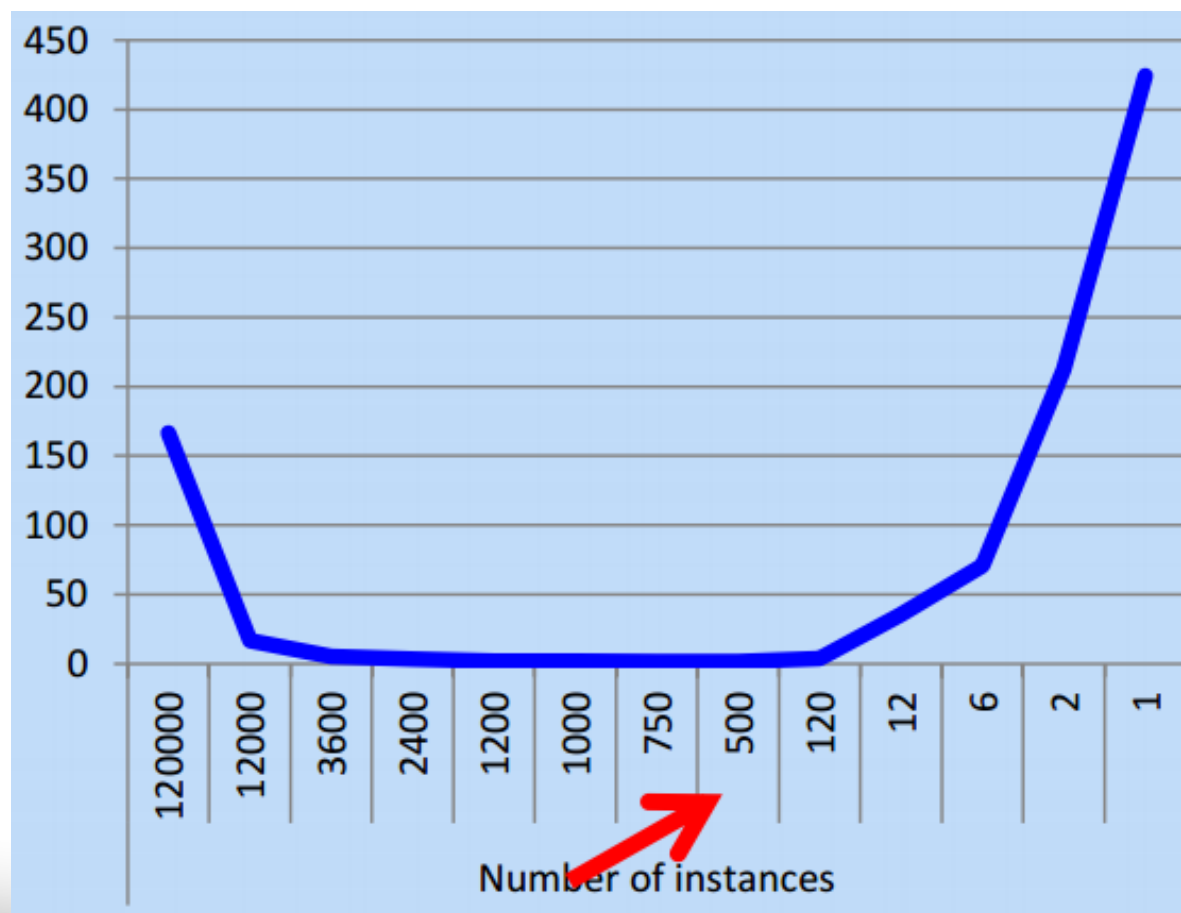


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Cloud Computing (Summer 2014)

NOAA CDR Pathfinder SST v5.3 – 31 data years, 1.2 million AVHRR images
Reprocessed in 1 day by 120 Amazon EC2 instances



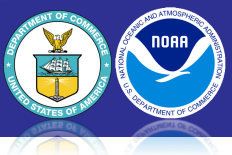
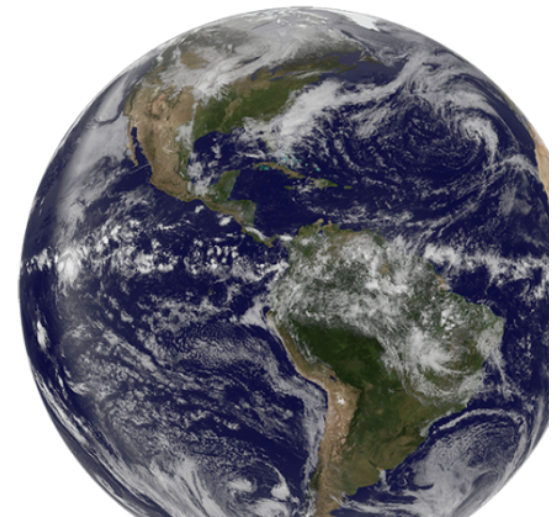
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Global Change Research

What lessons will you draw on for the future?

- New science capabilities for monitoring, understanding, and predicting global change will increasingly be provided by technological breakthroughs, but only if there is adequate capacity to assess the data, information, and knowledge



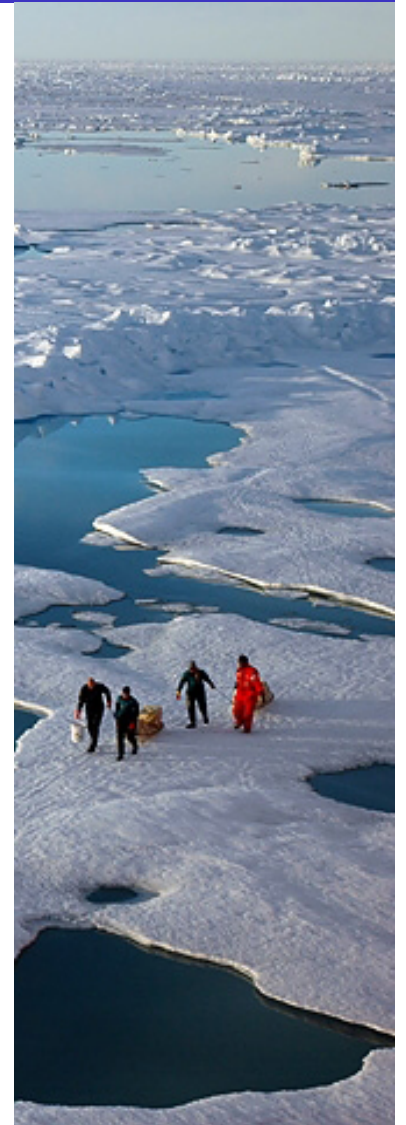
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The Future

Global Change Science – The Next 10-20 Years

- Temporal gaps and observing system homogeneity
- Maintaining low-medium tech observing systems that provide long-term insights
- Seasonal to Decadal Projections and Predictions
- Understanding the Water Cycle
- Assessment/Science a growing necessity



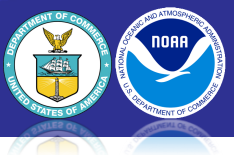
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The Future

Impediments and Opportunities

- Developing the infrastructure and resources needed to provide for interdisciplinary data sets and indicators of change (peer-reviewed, timely, and interoperable formats)
- Avoiding observing and effective data system gaps
- Understanding compound uncertainties across disciplines



Societal Needs

How is society's need for information about global change evolving?

- More practical questions focusing on what is needed for adaptation to sustain business and industry in a changing climate

What do you see as the critical role for science moving forward?

- Defining our certainties and uncertainties related to what we know and what we can predict in a way that can be used for business, industry and resource managers



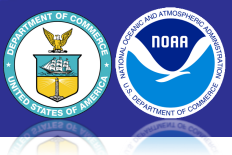
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Societal Needs

Are there tradeoffs between fundamental science and its application, and if so, how should they be managed effectively?

- Danger of blurring “swim lanes”...
Most appropriate to develop a new cadre of scientists who bridge the science and application “valley of death”



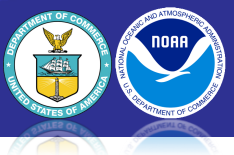
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AGCI's Role

How do you see AGCI's role evolving into the next 25 years?

- There is an unfilled niche in bridging the divide between research and operations/applications



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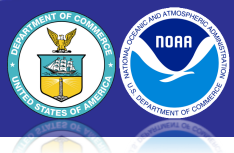
www.ncdc.noaa.gov
www.climate.gov



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