

From prehistoric ice cores to modern satellite observations - climate data and services from NOAA's National Centers for Environmental Information

Dr. Ed Kearns, Center for Weather and Climate
NOAA's National Centers for Environmental Information

Copernicus Climate Data Store Workshop 3 March 2015



History of NCEI's Center for Weather and Climate

- 1951: National Weather Records Center (NWRC) under the Weather Bureau. Consolidated Weather Bureau, Air Force, and Navy records in Asheville, North Carolina.
- 1965: Environmental Science Services Administration formed under the US Department of Commerce (Weather Bureau dissolved)
- 1970: NOAA is established under Commerce. NWRC renamed to National Climatic Center (NCC)
- 1984: NCC renamed National Climatic Data Center (NCDC) to emphasize the importance of the large quantity data
- **2015: NCDC merges with other NOAA Data Centers to create the National Centers for Environmental Information (NCEI)**



1950s

1960s

1970s

1980s

1990s

2000s

2010s



National Weather Records Center (NWRC) established

400 million punch cards store NWRC's data

Transition to tapes; scientific research growth

Millions of pieces of microfilm and microfiche store data

NCDC information used to monitor global weather and climate from the stone age to the space age

Nation's first Climate Reference Network station built and operated by NCDC

Next-generation satellites greatly increase NCDC holdings

3/3/2015

Copernicus Climate Data Store Workshop



NCEI's CWC (formerly NCDC) Strategic Vision

MISSION

Steward the United States' Climate Information

NCEI CWC is responsible for preserving, monitoring, assessing, and providing public access to the Nation's treasure of climate and historical weather data and information.

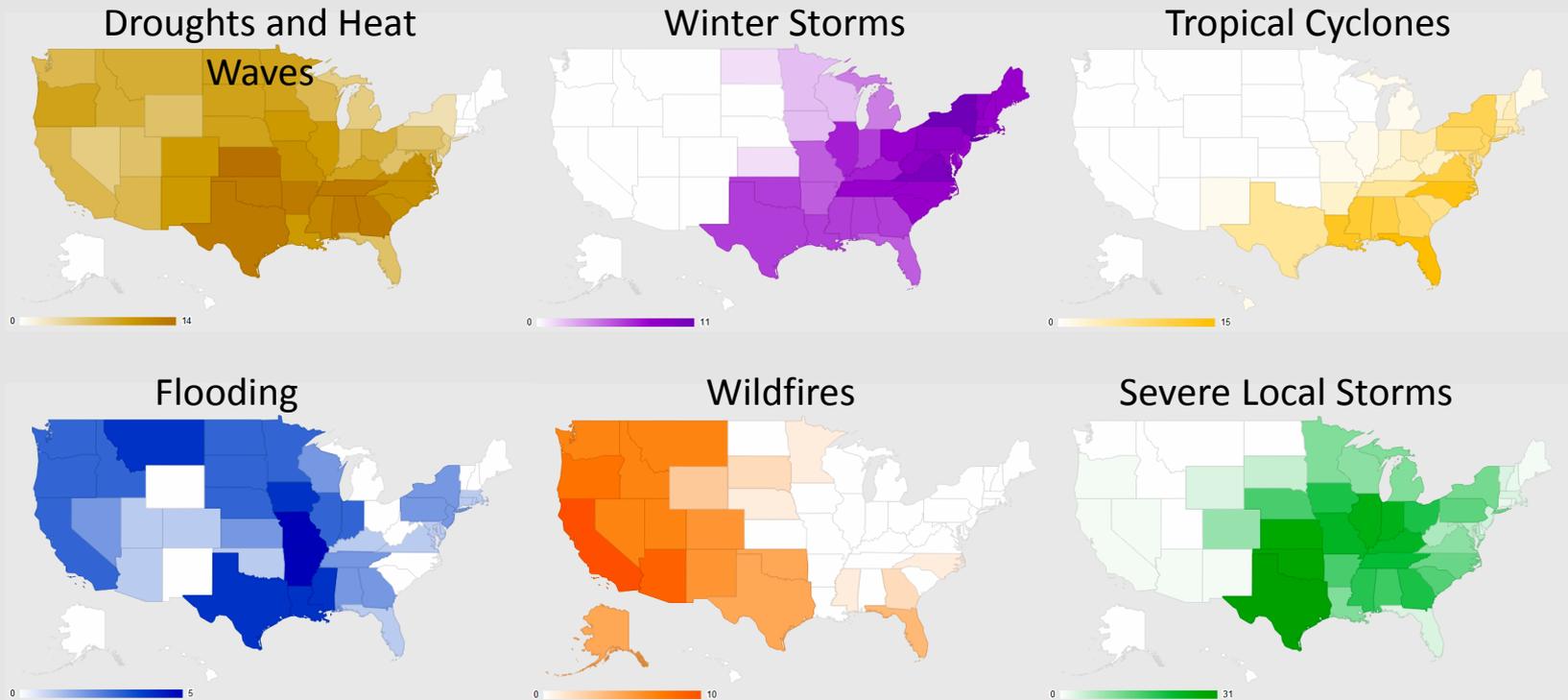
VISION

Be the United States' Trusted Authority on Climate and Historical Weather Information

NCEI CWC will be the most comprehensive, accessible, and trusted source of state-of-the-science climate and historical weather data, information, and climate monitoring.

The United States Has Economic Motivations for Increasing Access to Climate Information Products

U.S. Billion-Dollar Weather and Climate Disasters: 1980–2013



170 weather and climate disasters reached or exceeded \$1 billion during this period (CPI-adjusted)

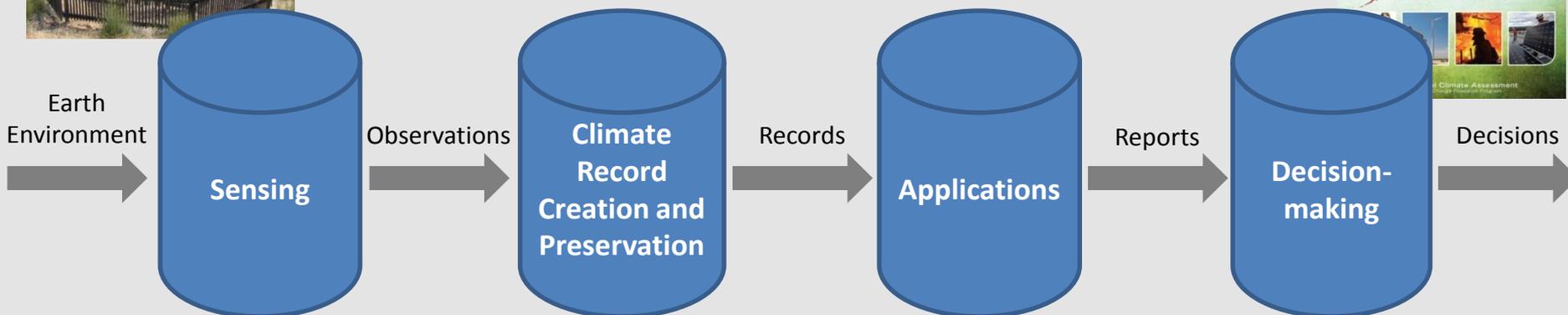
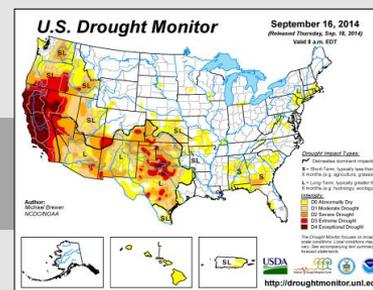
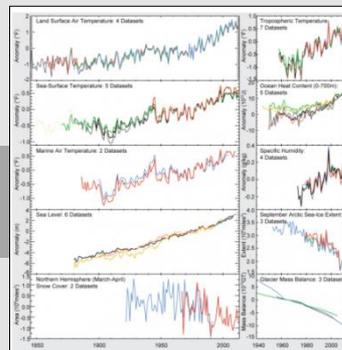
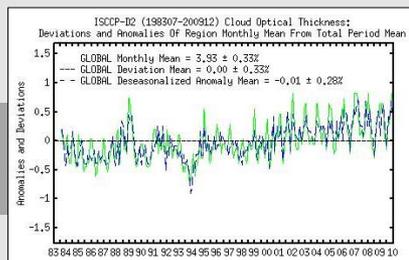
Please note that the map reflects a summation of billion-dollar events for each state affected (i.e., it does not mean that each state shown suffered at least \$1 billion in losses for each event)

NCEI Products Span from Local to Global on Weekly to Decadal Scales



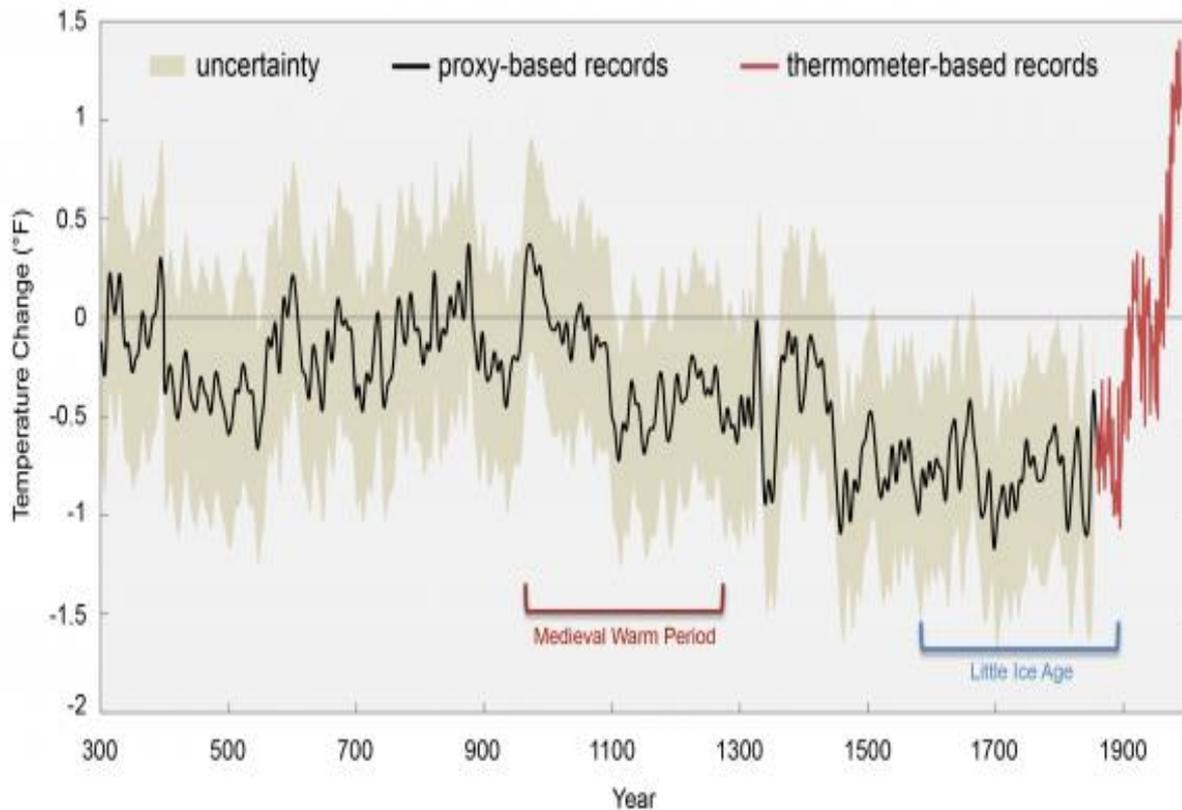
NCEI Supports the Full Information Lifecycle

- Makes foundational investments in climate information production and preservation.
- Supports others' application development and policy/decision-making.

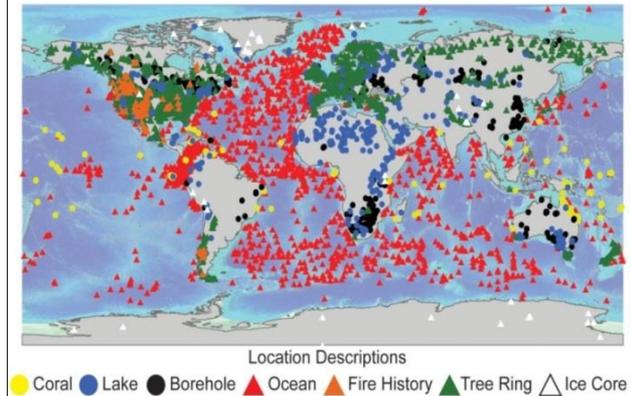


NCEI Begins Definition of the Climate Record with Paleoclimatology

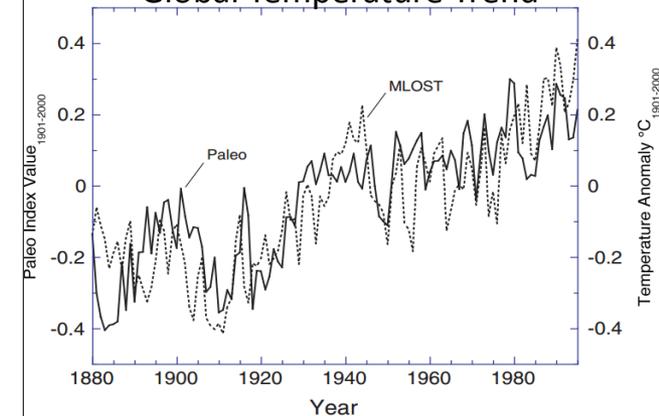
1,700 Years of Northern Hemisphere Temperature Change from Proxy Data



Locations and Types of Paleo Records

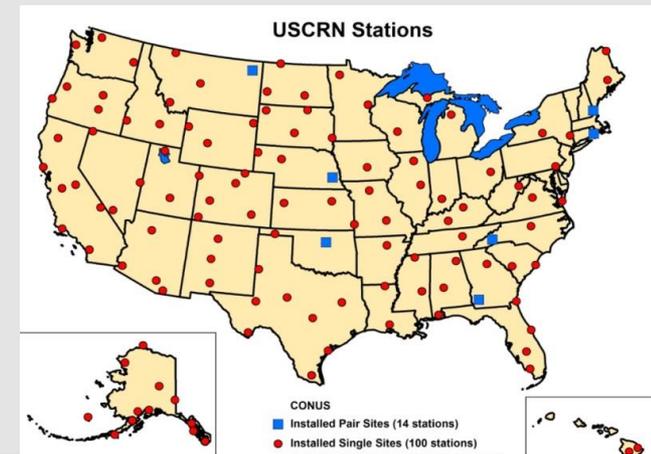


Independent Paleo Record of Global Temperature Trend



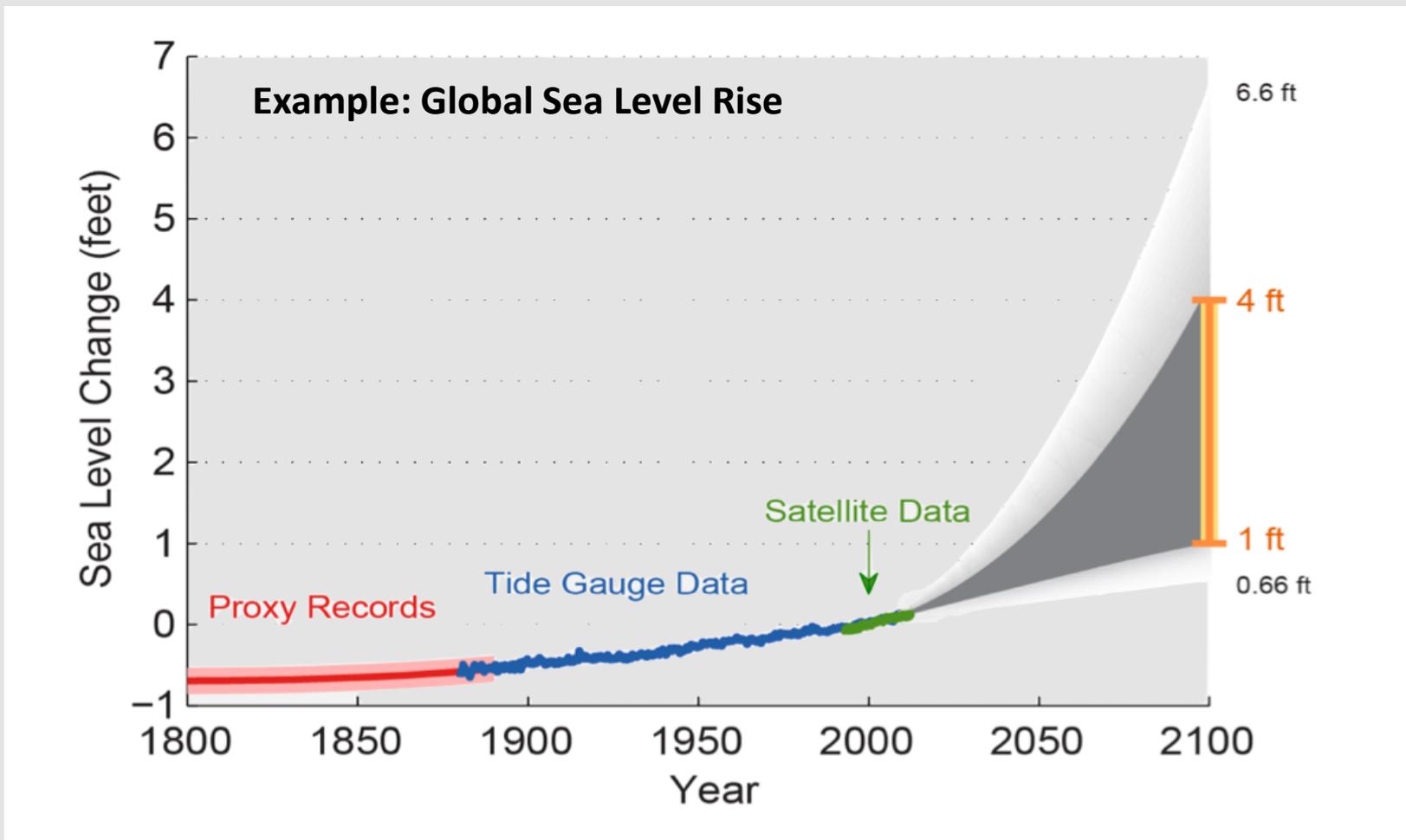
NCEI Operates the U.S. Climate Reference Network (USCRN)

- Follows the GCOS Climate Monitoring Principles
- Three independent measurements of multiple essential climate variables
- Well-calibrated and highly accurate observations
- Pristine, stable environments
- The standard for climate measurements



USCRN Shielded Precipitation Gauge at Redding, CA

NCEI Combines Different Data Sources for Climate Records



NCEI provides national and international leadership in climate data and information, science, stewardship, and service/assessment

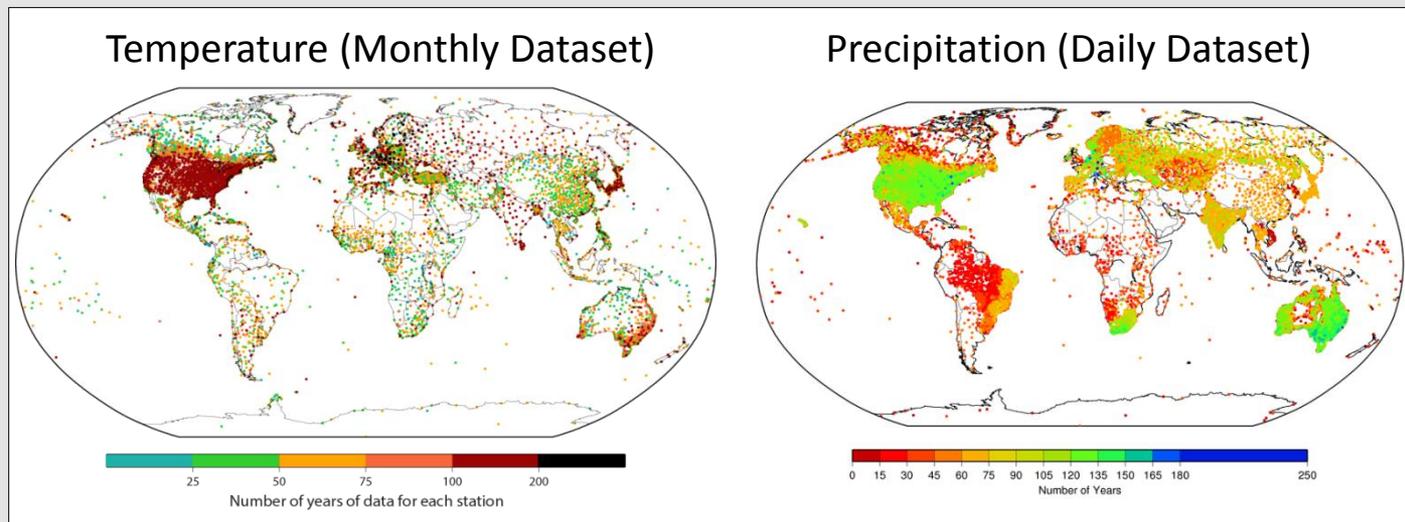
- World's largest archive of climate, weather, and environmental information (>18 PB)
- Multiple "gold standard" datasets, e.g. temperature
- Frequent papers in major scientific journals
- Leadership in WMO, GCOS, GEO, IPCC...
- US National Climate Assessment
- BAMS State of the climate
- US Global Change Research Program leadership since 2010
- Extensive involvement in US national media

NCEI are the United States' go-to Centers for retrospective weather and climate data

NCEI Produces the Gold-Standard Global Land Surface Temperature Dataset



- NCEI monitors changes in global land surface temperature using the Global Historical Climatology Network-Monthly (GHCN-M) dataset
- This dataset provides monthly average temperatures from over 40,000 stations, some of which contain records back more than 300 years
- Considered the most comprehensive suite of global temperature and precipitation observations in the world

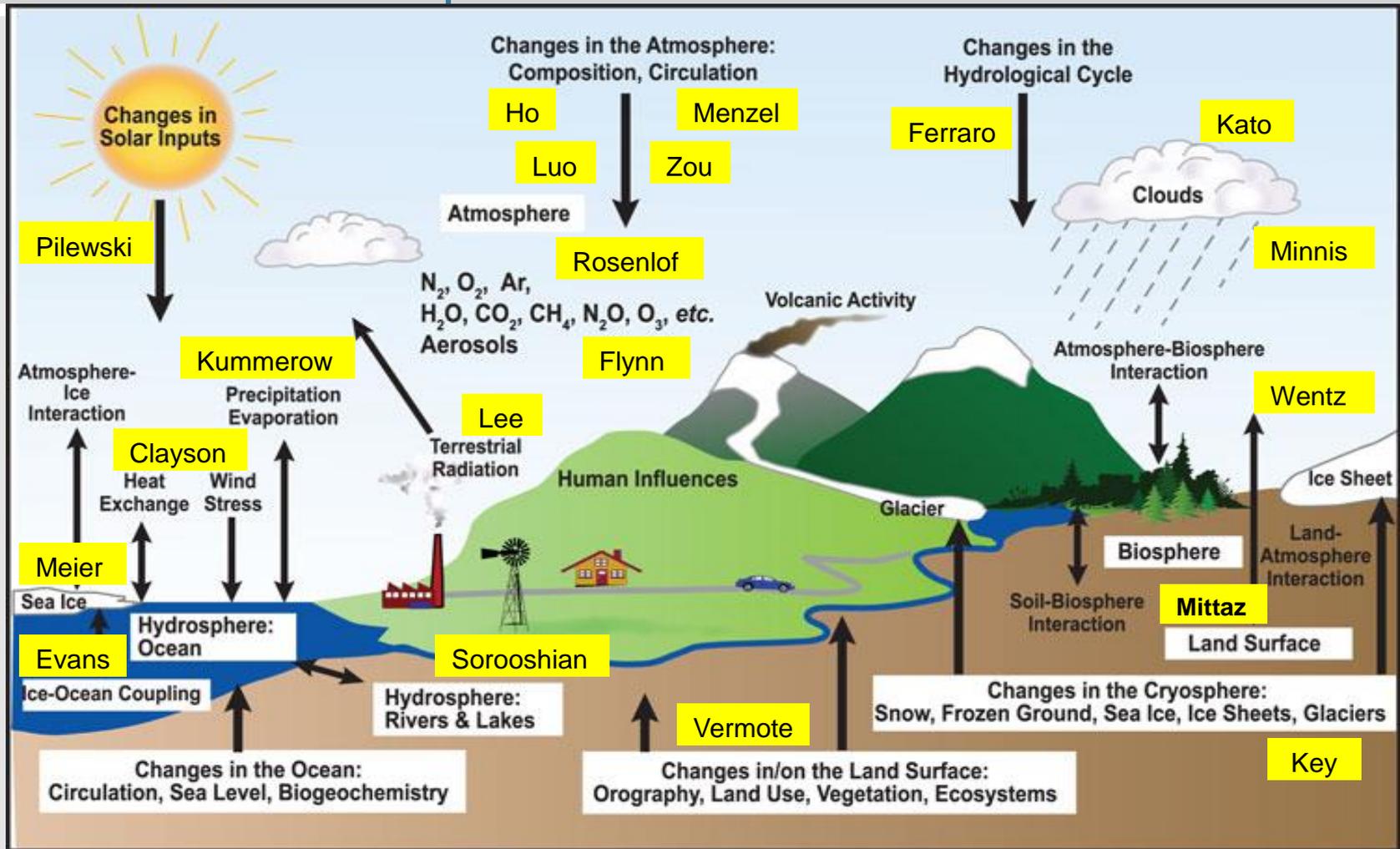




NCEI's Operational Climate Data Records (CDRs)

- By applying knowledge gathered over time about instruments' performance and sensor characteristics, environmental data are reprocessed to create consistent and homogenized long-term records.
- NOAA's satellite CDRs comprise its longest record of global operational satellite measurements.
- NOAA satellite, in situ, and blended CDRs are sustained in an operational environment, which is critical for supporting decision-making in a changing climate, and thus for the world's resilience to climate variability.

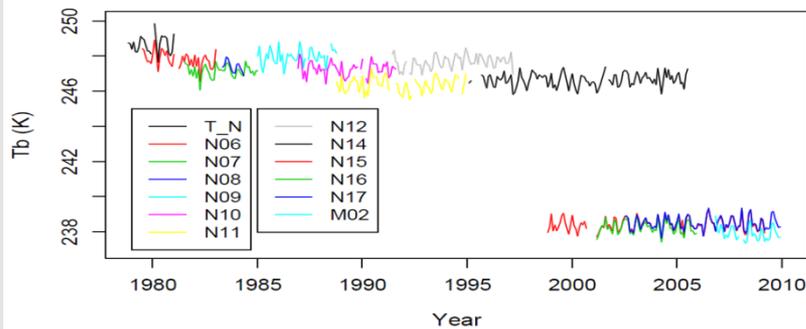
Current NOAA Operational CDR Inventory (>26) Spans the Environment



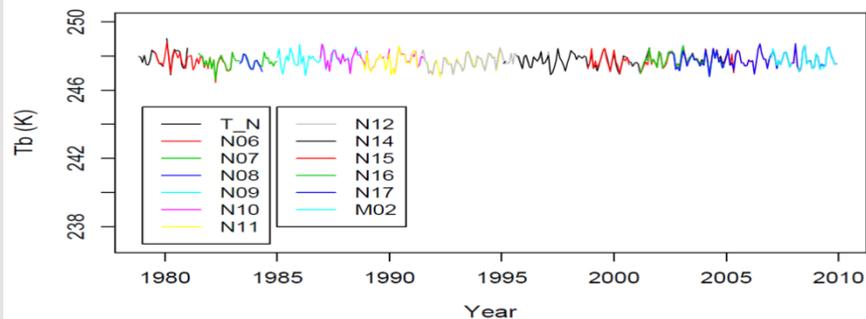
What is the advantage of using NCEI CDRs?

(High Quality Data: Inter-calibration and Homogenization Reduce Artifacts Imparted by Observing Systems, Facilitating Meaningful Comparisons in Space and Time)

HIRS BT Timeseries, before inter-calibration



HIRS BT Timeseries, after inter-calibration



Operational weather products are produced rapidly to potentially save life and property



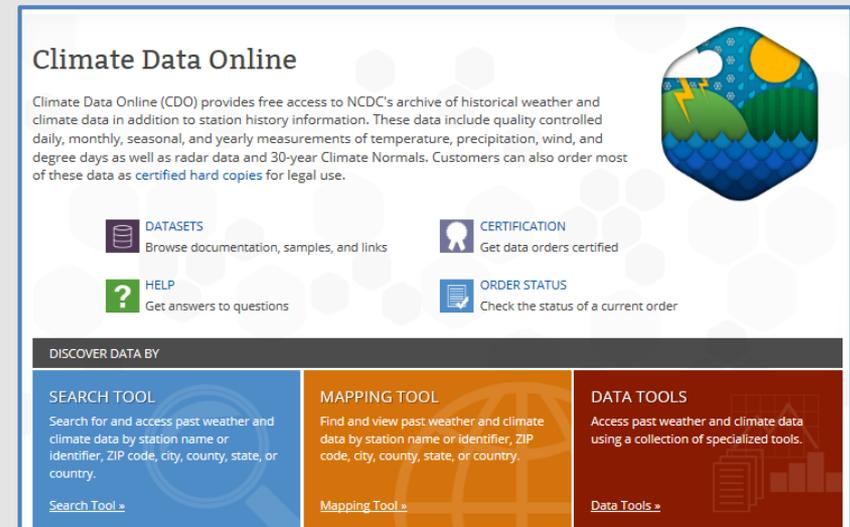
Climate Data Records (CDRs) describe climate through rigorous cross-calibration and reprocessing with advanced algorithms, ancillary data and evolved instrument understanding.



NCEI Data Access

Climate Data Online (CDO) System

- www.ncdc.noaa.gov
- Centralized access to numerous US and global datasets and products
- Web Services allow users direct machine-to-machine access for use in applications (WMS, WFS, KML/KMZ, etc.)
- Underlying structure includes Oracle databases with tiered server infrastructure
- Services continue to be built-out for additional datasets and products



Climate Data Online

Climate Data Online (CDO) provides free access to NCDC's archive of historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals. Customers can also order most of these data as certified hard copies for legal use.

DATASETS
Browse documentation, samples, and links

CERTIFICATION
Get data orders certified

HELP
Get answers to questions

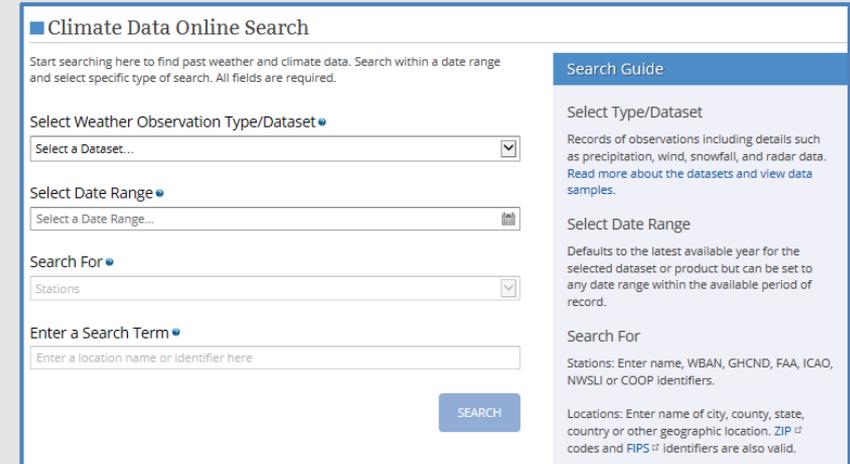
ORDER STATUS
Check the status of a current order

DISCOVER DATA BY

SEARCH TOOL
Search for and access past weather and climate data by station name or identifier, ZIP code, city, county, state, or country.
[Search Tool >](#)

MAPPING TOOL
Find and view past weather and climate data by station name or identifier, ZIP code, city, county, state, or country.
[Mapping Tool >](#)

DATA TOOLS
Access past weather and climate data using a collection of specialized tools.
[Data Tools >](#)



Climate Data Online Search

Start searching here to find past weather and climate data. Search within a date range and select specific type of search. All fields are required.

Select Weather Observation Type/Dataset ●
Select a Dataset...

Select Date Range ●
Select a Date Range...

Search For ●
Stations

Enter a Search Term ●
Enter a location name or identifier here

SEARCH

Search Guide

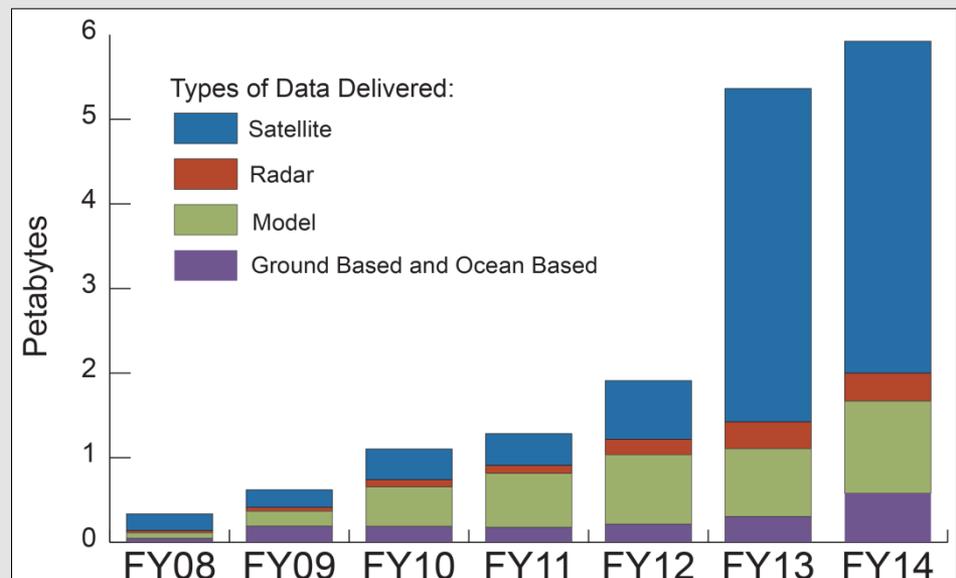
Select Type/Dataset
Records of observations including details such as precipitation, wind, snowfall, and radar data. [Read more about the datasets and view data samples.](#)

Select Date Range
Defaults to the latest available year for the selected dataset or product but can be set to any date range within the available period of record.

Search For
Stations: Enter name, WBAN, GHCND, FAA, ICAO, NWSLI or COOP identifiers.
Locations: Enter name of city, county, state, country or other geographic location. ZIP ¹⁷ codes and FIPS ¹⁷ identifiers are also valid.

NCEI Is Responding to an Accelerating User Demand

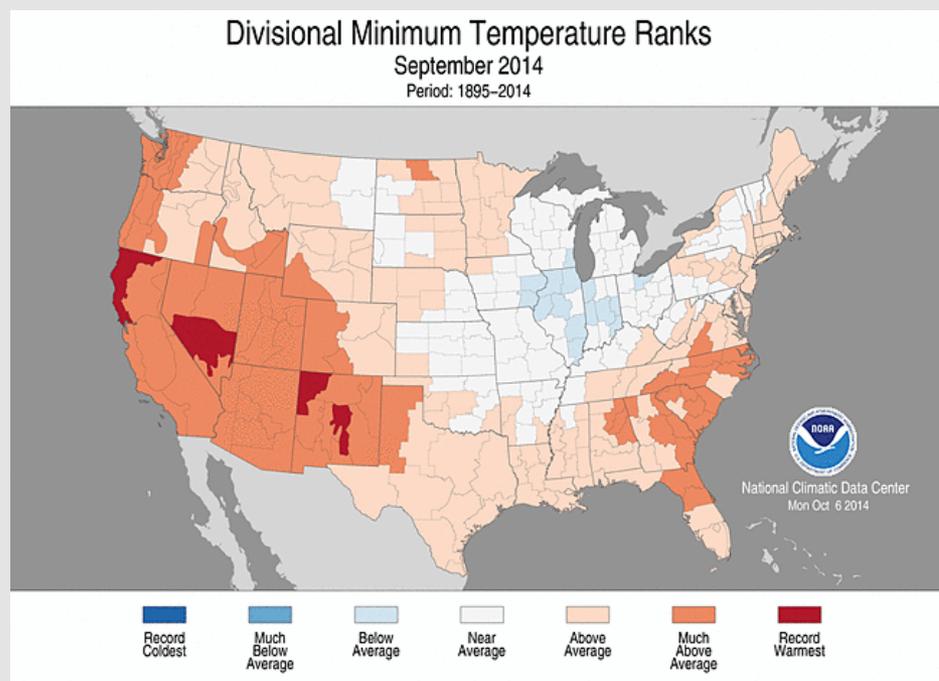
- Now serving over 5 petabytes of climate data annually
- Provide safe storage of over 18 petabytes
- Service over 20,000 personal contacts with users across economic sectors, regions, and societal challenges



Who Are Our Users? NCEI's General User Profile

Fraction (%)	Data Expertise	Stereotypical User	Data or Info Need	Preferred Format	Access Volume	Access Frequency
70	Low	Business, media, public	Qualitative	Point-and-click, graphics, assessments	Low	High
15	High	Researchers, Climate consultancies	Quantitative	Digital downloads	High	Low
15	High	Value-added Providers (database scrapers)	Quantitative	Digital downloads	Low	High

Most Users Increasingly Only Want Expert Interpretations



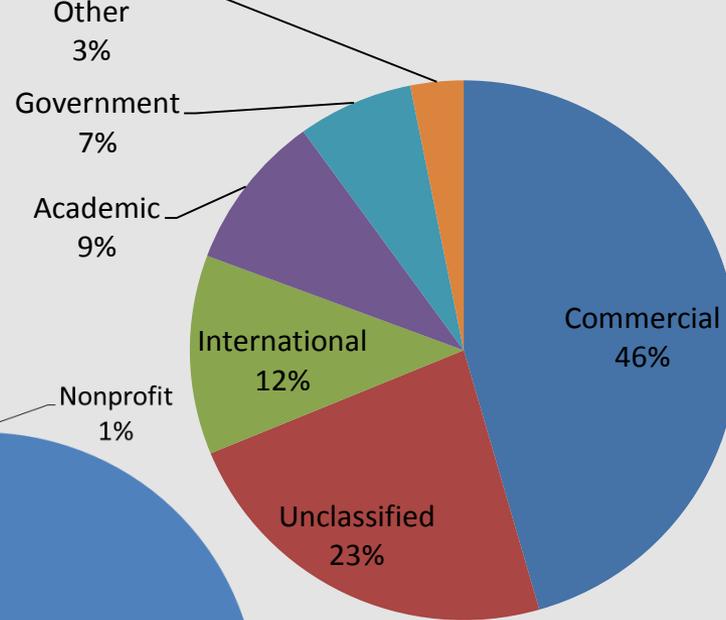
• Aspects of Monitoring

- **Average** values (13.3°C)
- Measures of **difference** ($+1.8^{\circ}\text{C}$ above normal)
- Measures of **unusualness** (much above average = top 10%)
- Measures of **trend** (increasing at 0.5°C per century)
- Measures of **impact** (34% of corn reported in poor condition)

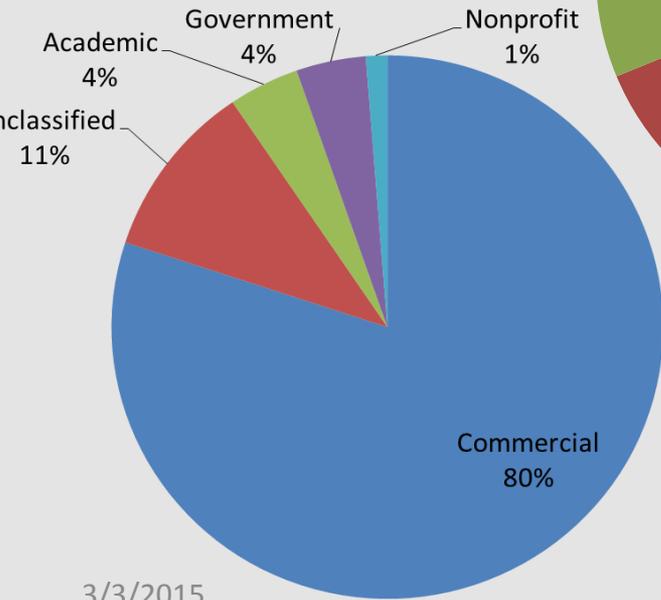
Services and Stewardship: NCEI provides authoritative services in climate, science, data, and information preservation.

NCEI Users of Climate Data From All Sectors

NCEI CWC Online User Profile



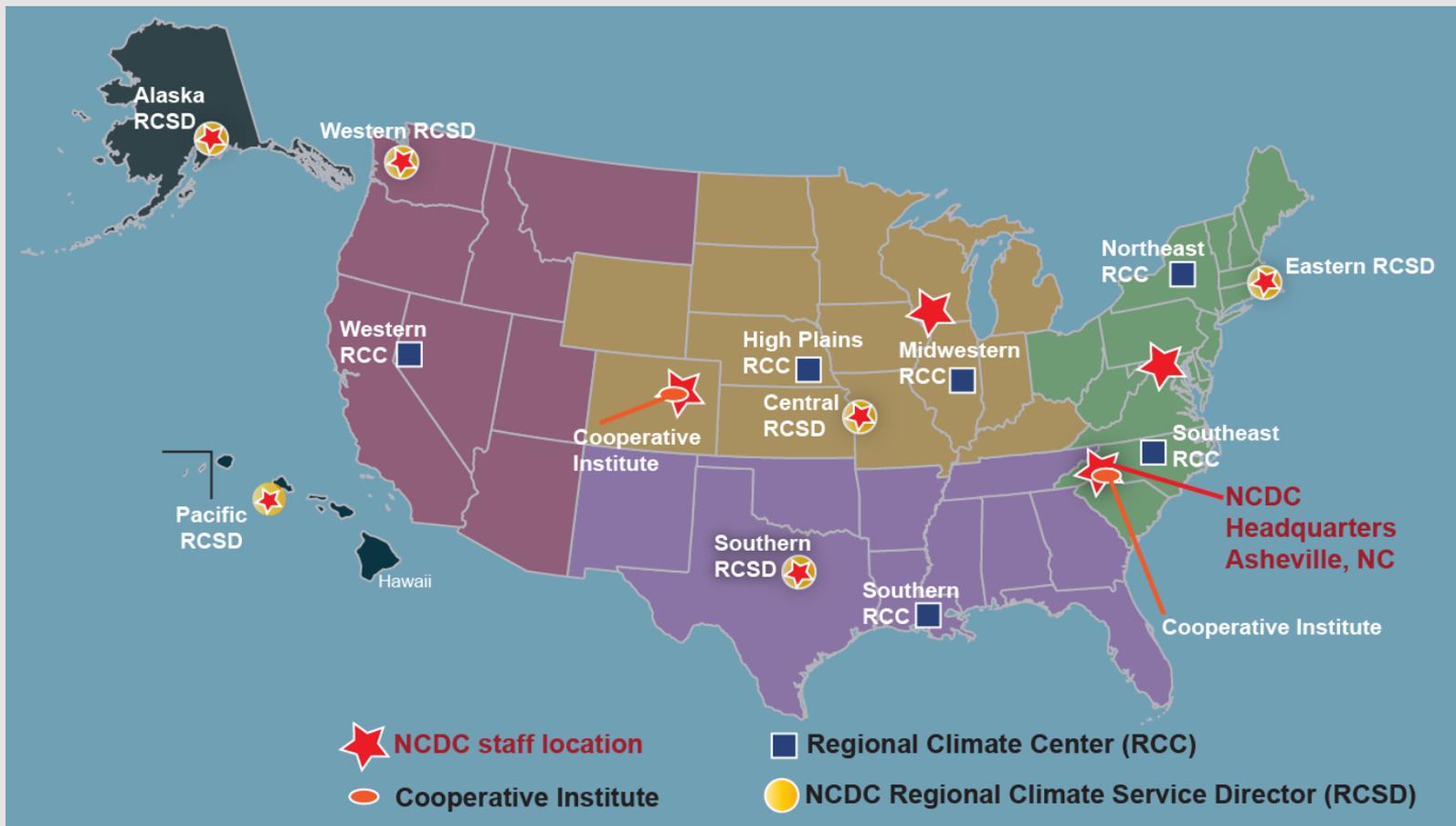
Nonstandard Data Requests by Sector



For past 12 months	
Calls:	15,588
E-Mails:	7,056
Faxes:	223
Letters:	236

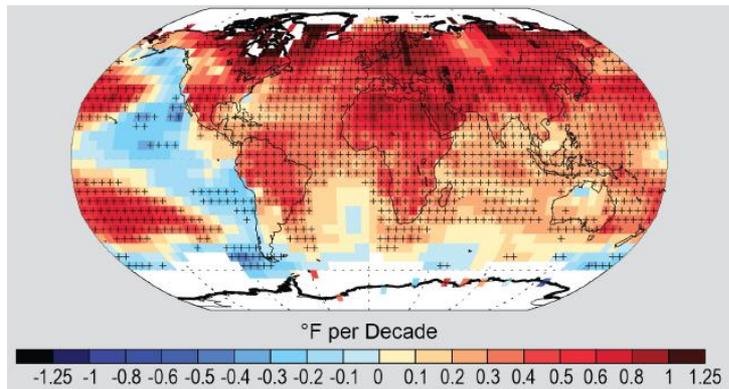
- Water resource managers rely on the information to help officials and planners make informed decisions about a finite resource
- The American Society of Heating, Refrigerating, and Air Conditioning Engineers uses the data to develop heating/cooling engineering standards
- Insurance and reinsurance companies make use of weather and climate data to calibrate their catastrophe models

National placement of NCEI climate staff to help provide services and gather requirements

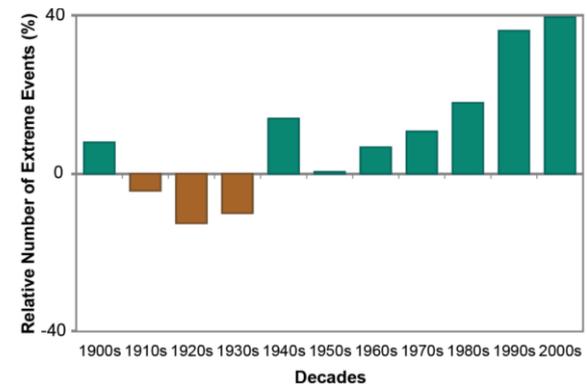


NCEI Monitors the State of the Climate

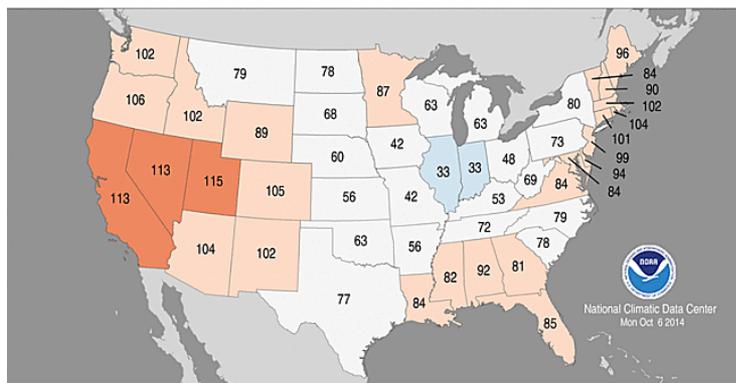
Global Temperature Trends 1979–2012



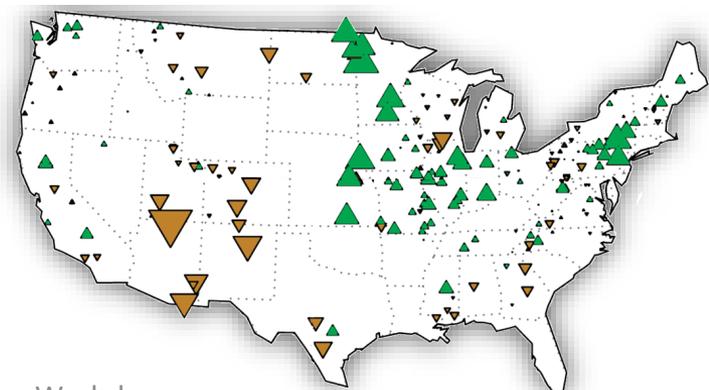
Decadal Trends in Very Heavy Precipitation



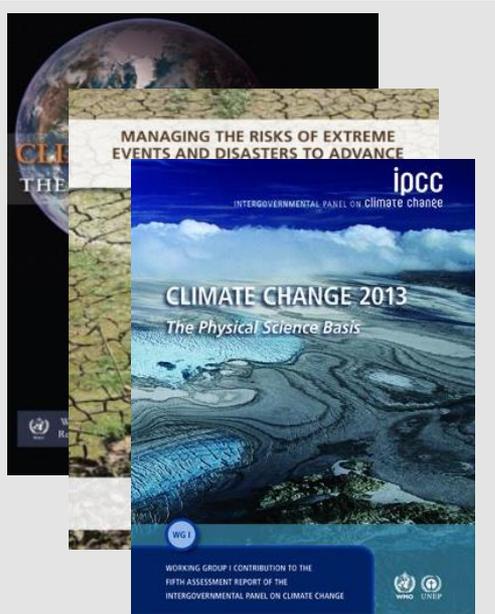
Statewide Average Temperature Ranks September 2014



River-Flow Trends in Annual Maximum for 85–127 Years Ending in 2008

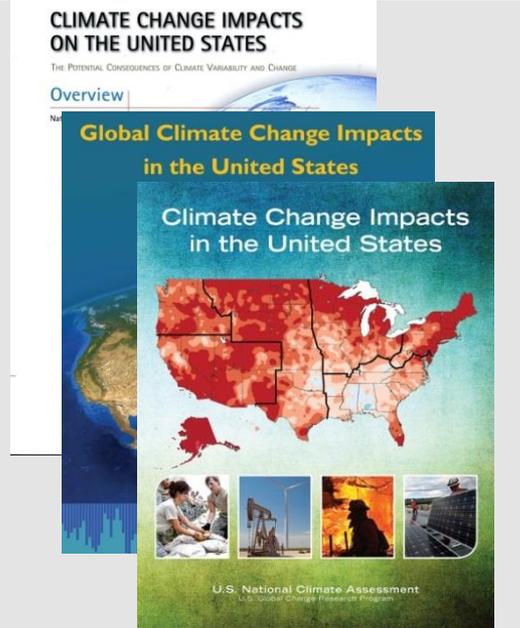


NCEI Assesses the Earth's Climate with International, National, and Annual Assessments



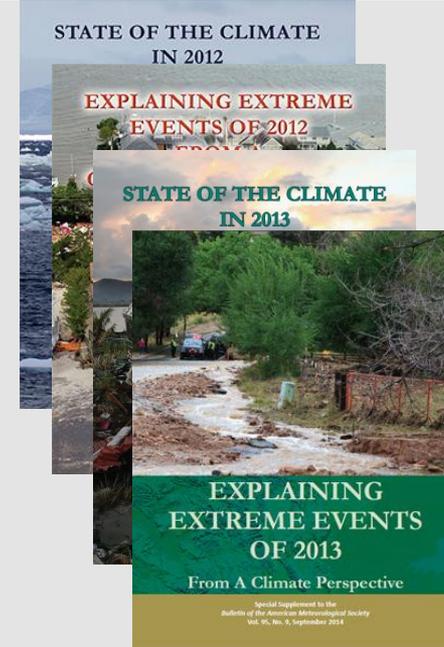
International Assessments

- Three NCEI lead authors and review editors on Fourth Assessment Report
- Two NCEI lead authors on Fifth Assessment Report
- Two NCEI lead authors on Special Report on Extremes



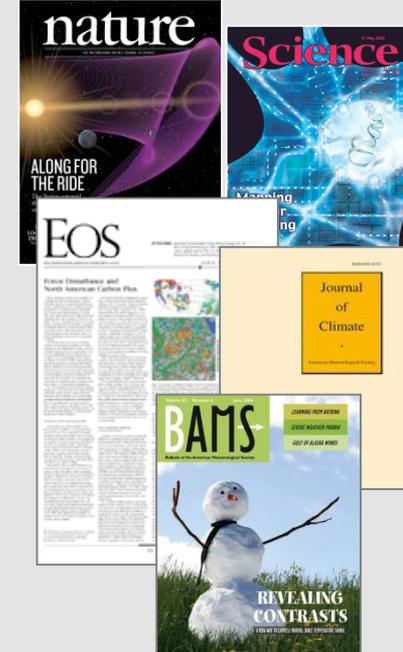
National Assessments

- NCEI provides leadership and lead authors for all National Climate Assessments
- NCEI hosts National Assessment's Technical Support Unit



Annual Assessments

- NCEI coordinates 425 authors from 57 countries
- Covered by all major news networks, briefed to US Congressional staff



Journal Articles

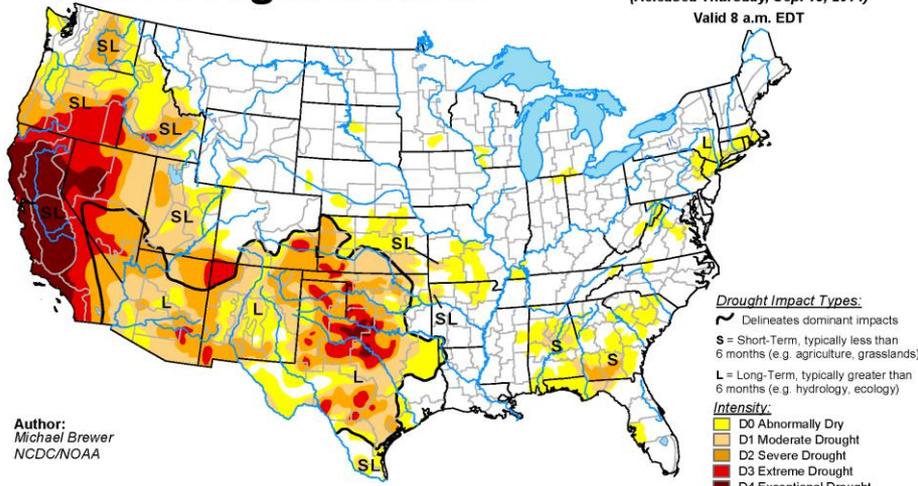
- NCEI publishes over 50 articles annually in leading scientific journals such as Nature, Science, and BAMS

NCEI Tracks Drought Through the National Integrated Drought Information System (NIDIS)

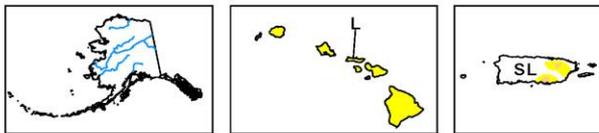
- NCEI hosts Drought.gov and tracks state of drought weekly through the U.S. Drought monitor in partnership with other agencies
- Expanded to North America through our international partnerships

U.S. Drought Monitor

September 16, 2014
(Released Thursday, Sep. 18, 2014)
Valid 8 a.m. EDT



Author:
Michael Brewer
NCDC/NOAA



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

USDA
National Drought Mitigation Center

<http://droughtmonitor.unl.edu/>

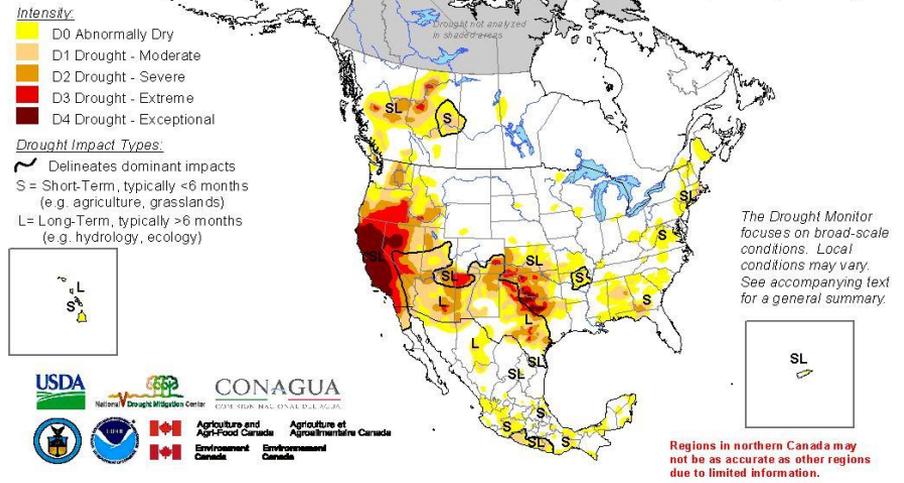
North American Drought Monitor

September 30, 2014
Released: Friday, October 10, 2014

<http://www.ncdc.noaa.gov/nadm.html>

Analysis:
Canada - Trevor Hadwen
Mexico - Reynaldo Pascual
U.S.A. - Brian Fuchs*
Richard Heim

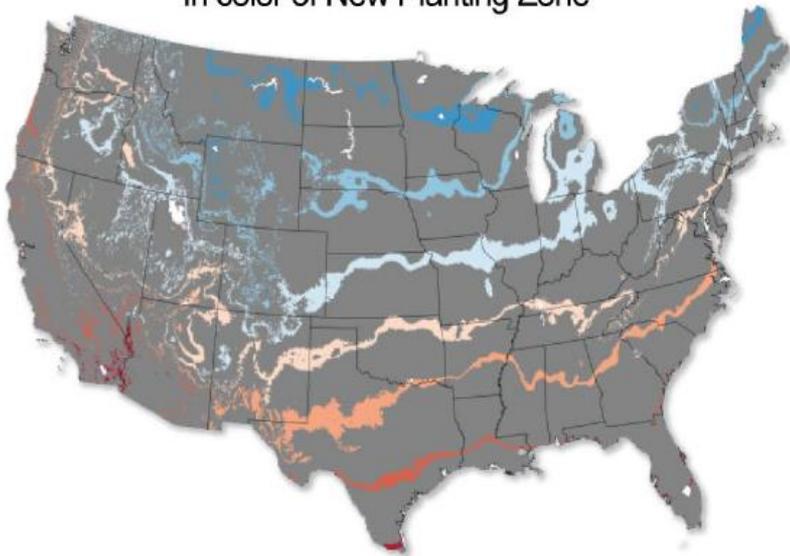
(* Responsible for collecting analysts' input & assembling the NADM map)



NCEI Produces the United State's Authoritative Climate Normals

- Used extensively by agriculture, engineering, energy planners, and others
- Below: shifts in plant heartiness zones

Zone Changes in Past 10 Years
In color of New Planting Zone



Zone Changes in Next 30 Years
In color of New Planting Zone



Average Annual Extreme Minimum Temperature by Climate-Related Planting Zone





Challenges and Opportunities

- How can NCEI best meet the growing demand for data access?
 - Demands are currently overtaxing our personnel and computational capabilities
- How to meet the growing demand for expert monitoring and assessment capabilities
 - President Obama's Climate Data Initiative
 - Science-certified services for U.S. Government, Industry, and the public
- How does NCEI best identify user requirements in an emerging and evolving community of practice?
 - Climate information industry is growing, but slowly
 - Production of climate information records and summaries
 - Feeding of data-hungry applications
 - Regional and local interest in tailored/downscaled products
- How to best work with our international and national partners on providing climate data and services?



Help coming from emerging climate information platforms?

- Climate information “platforms” are emerging through partnerships between US industry and government to aid in data analysis and distribution. (Some technical advances will be discussed in other US presentations in this workshop.)
- NCEI’s responsibility encompasses the preservation and stewardship of all the algorithms, code, docs involved in a climate data records – and will be needed by future climate information platforms.
- While NCEI waits for the infrastructure to be available from/with NOAA and its industry partners, the NCEI is focusing on:
 - Ensuring operational sustainment of its CDRs and information products
 - Making the data ready/portable for dissemination (standards)
 - Describing the data well (documentation, metadata) to enable discovery
 - Preserving and describing the algorithms, workflows, and ancillary data
 - Identifying and supporting uses (user requirements)

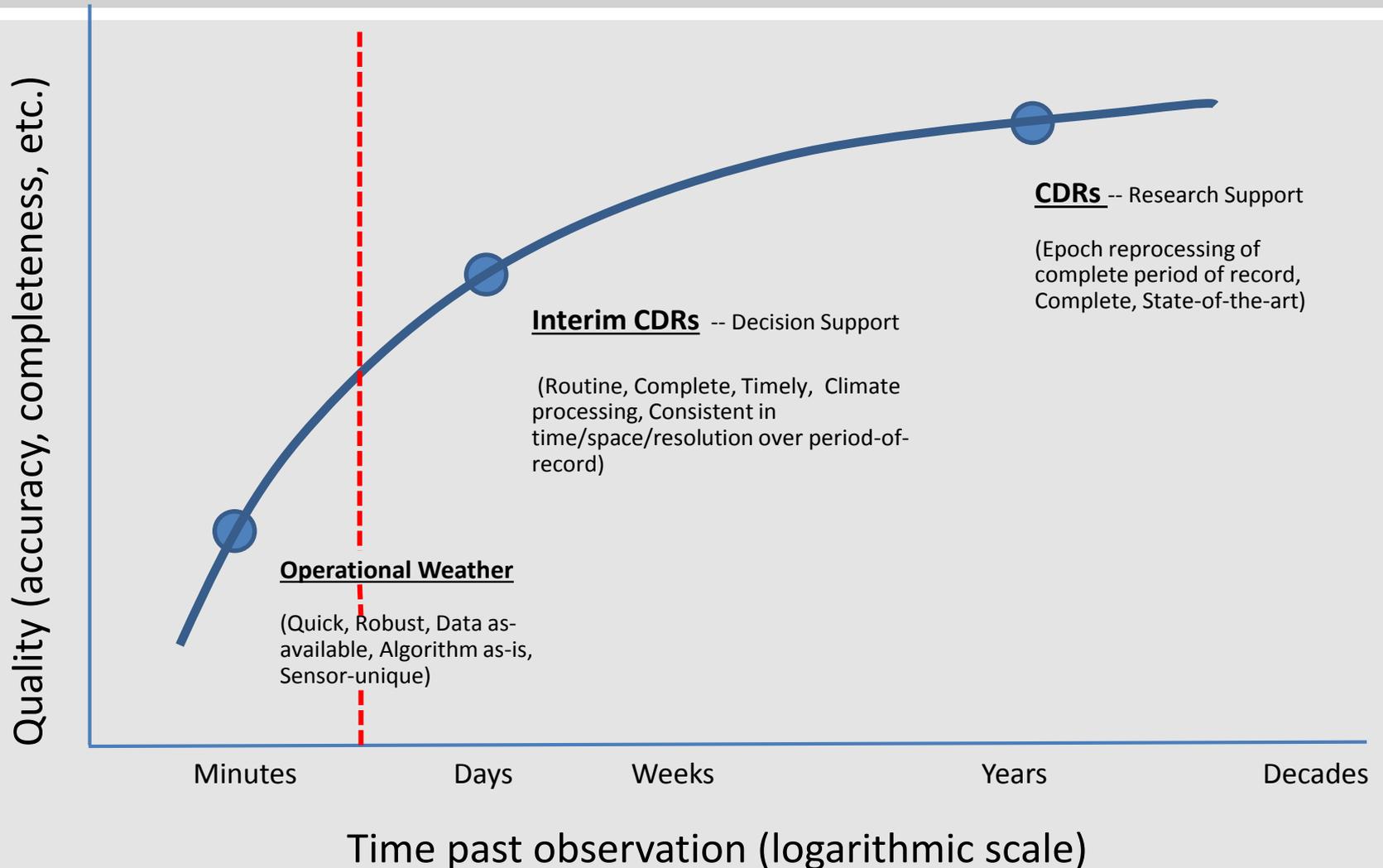


Questions?



Backup slides

CDRs Support Decision Support Applications at Time Scales Longer than a Week

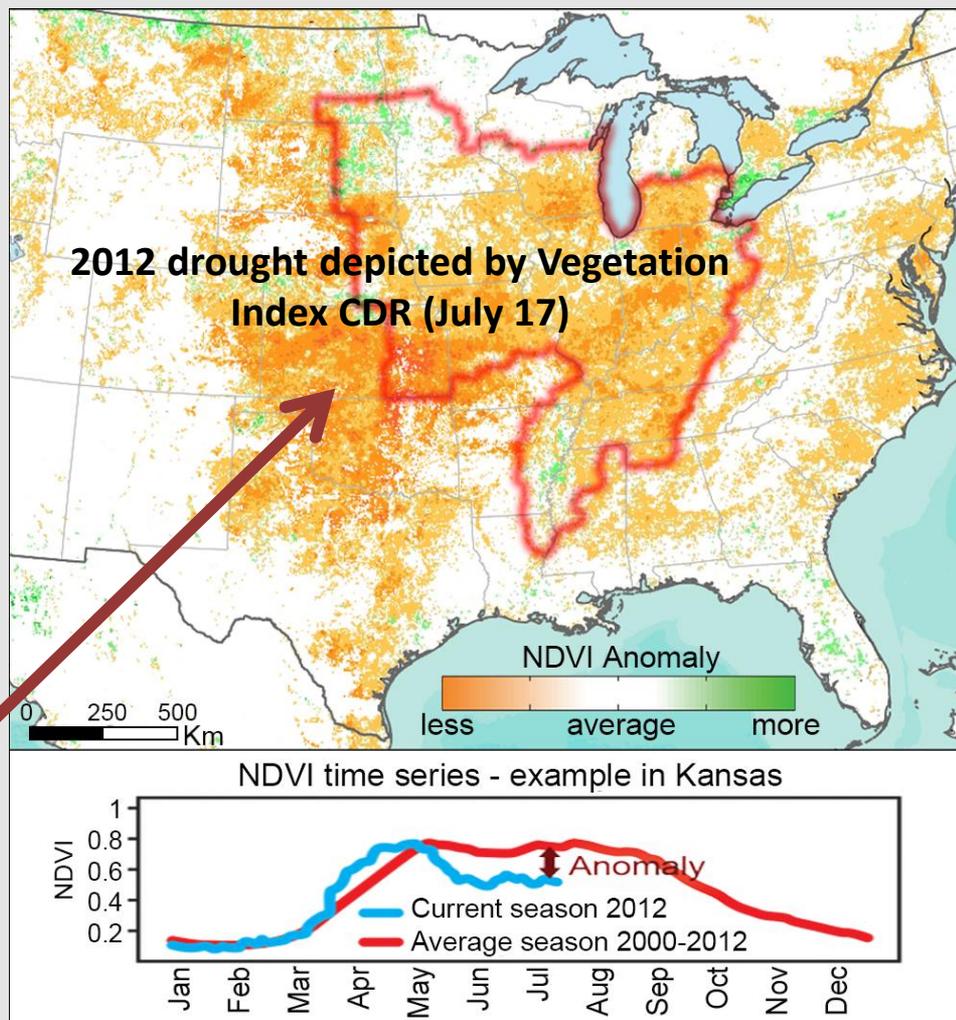


NCEI CDRs Supporting Farming and Agribusiness

Example: NVDI Provides historical context for Drought

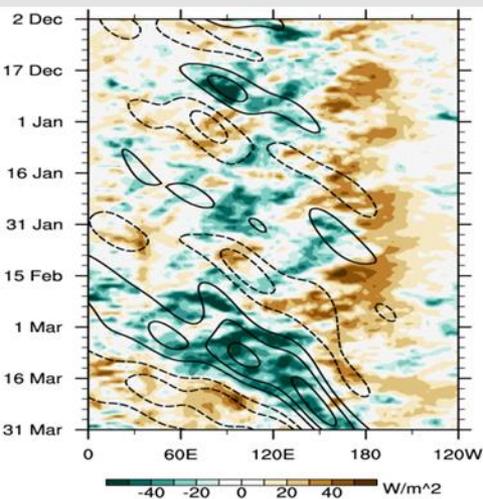
- 5 km resolution, “wall-to-wall” (globally)
- Historical record from 1981- to current
- Collateral products
 - Surface Reflectance
 - Leaf Area Index (LAI)
 - FPAR

Primary U.S. corn and soybean region

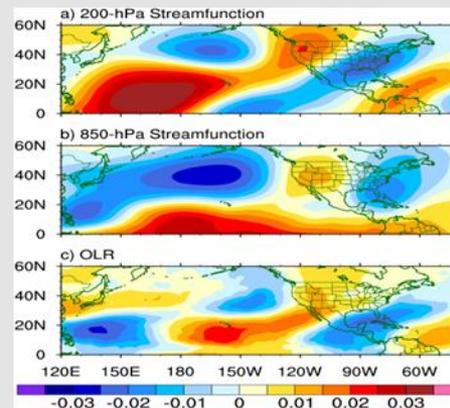


CDRs are being used to improve Monthly to Seasonal forecasts

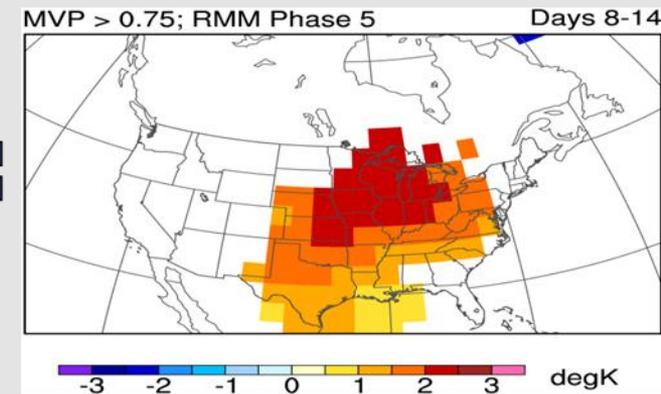
Satellite CDRs



Reanalysis



Improved 2-week Forecast

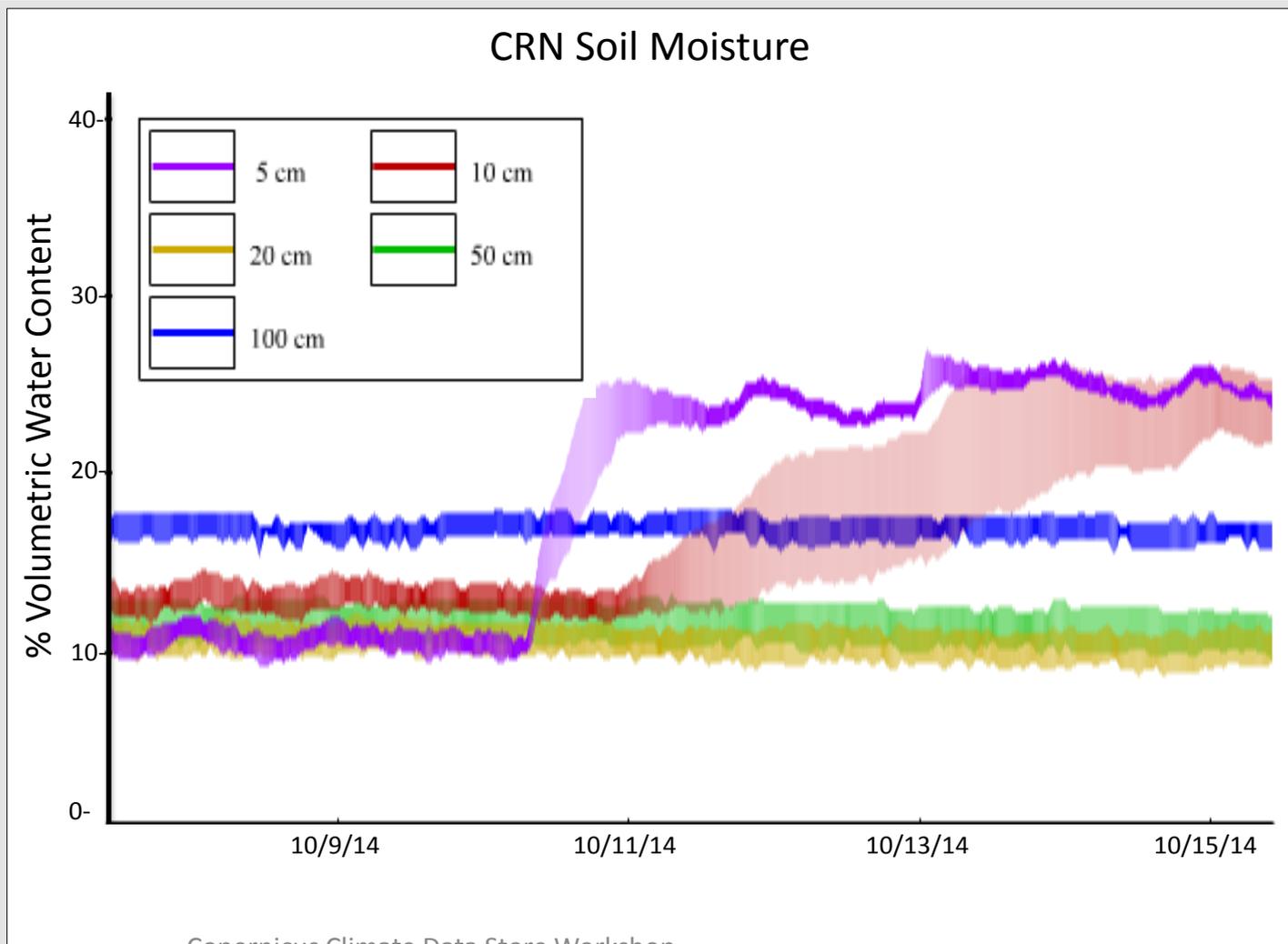
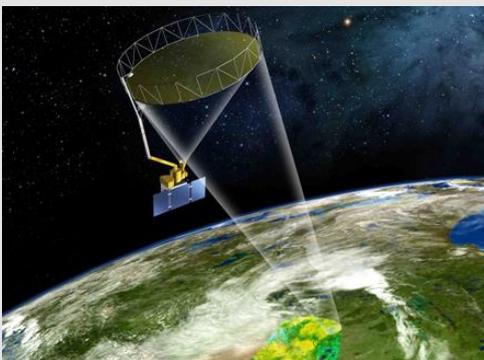


- NOAA's Outgoing Longwave Radiation (OLR) CDR is used to measure the Madden-Julian Oscillation (MJO) evolution
- Reanalysis leads to estimates of the future MultiVariate Pacific-North American (MVP) index
- MJO plus MVP provides a useful forecasting tool for future extratropical responses over US

Courtesy of Dr. Carl Shreck

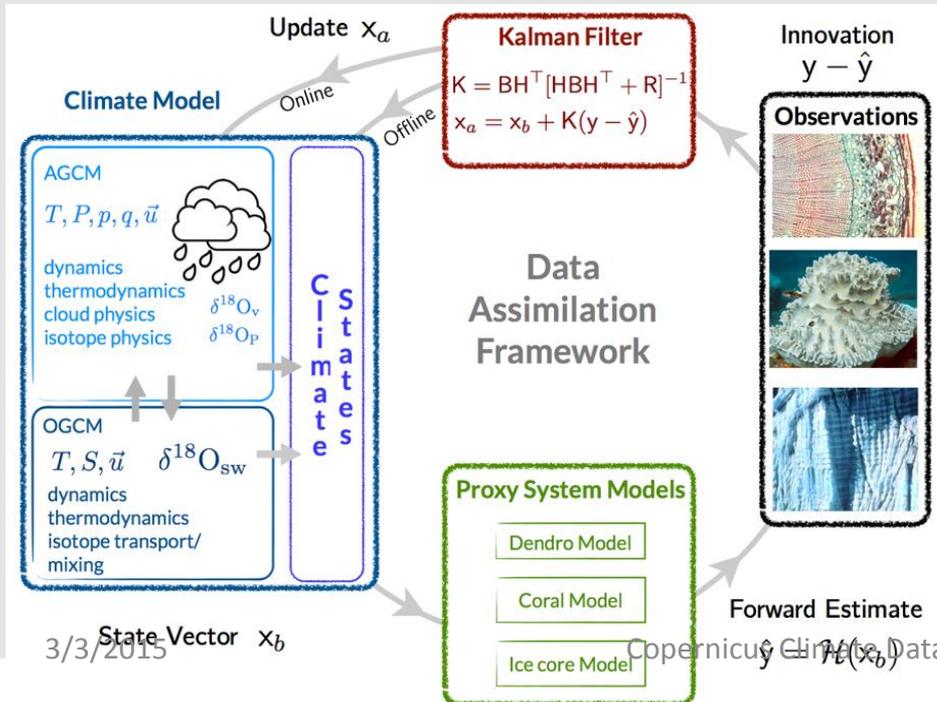
Climate Reference Network and Validation/Verification of Climate Data Records

NASA SMAP Satellite



Paleo-Reanalysis

- Paleo Reanalysis provides a powerful new tool allowing complete climate fields to be reconstructed into the far past – which is not now possible.
- A key outcome – **such as for the current California drought** – is to help ecosystems, communities, and economies become more resilient in the face of change by better knowing the full range of possible climate extremes.

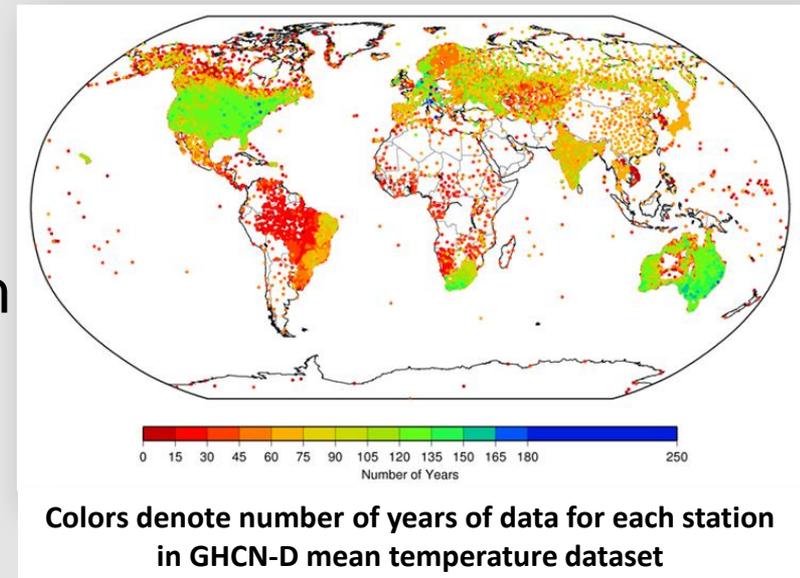


1. Identify the mean annual climate state from a coupled model ensemble
2. Express the modeled climate state as an expected set of proxy observations (e.g. tree ring widths) using a "forward model" that converts climate parameters into proxy measurements
3. Compare the expected proxy observations derived from the model state with actual proxy data, the difference is information to incorporate (*called the "innovation"*)
4. Incorporate the innovation information to update the mean annual climate (offline)
5. Repeat with proxy data for each year there is appropriate proxy data

GHCN-Daily

- The world's largest single collection of daily in situ climate data
 - More than 2.3 billion daily observations
 - Earliest value from January 1, 1763
 - Latest value from yesterday
 - ~30,000 temperature stations
 - ~92,500 precipitation stations
 - ~40,000 snowfall or snow depth

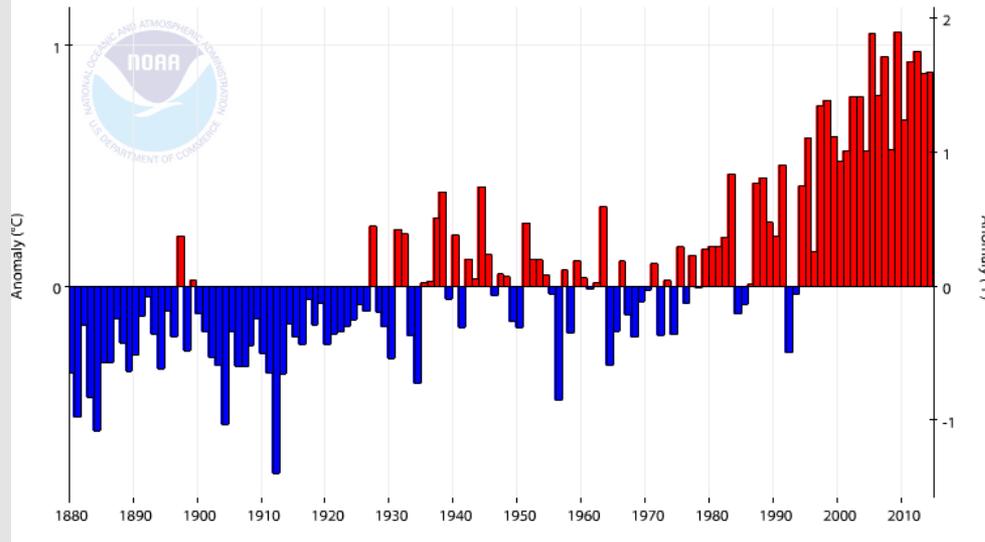
Robust global coverage with long periods of record in North America, Europe, Australia, and South Africa



GHCN-Monthly (Monitoring and Assessment)

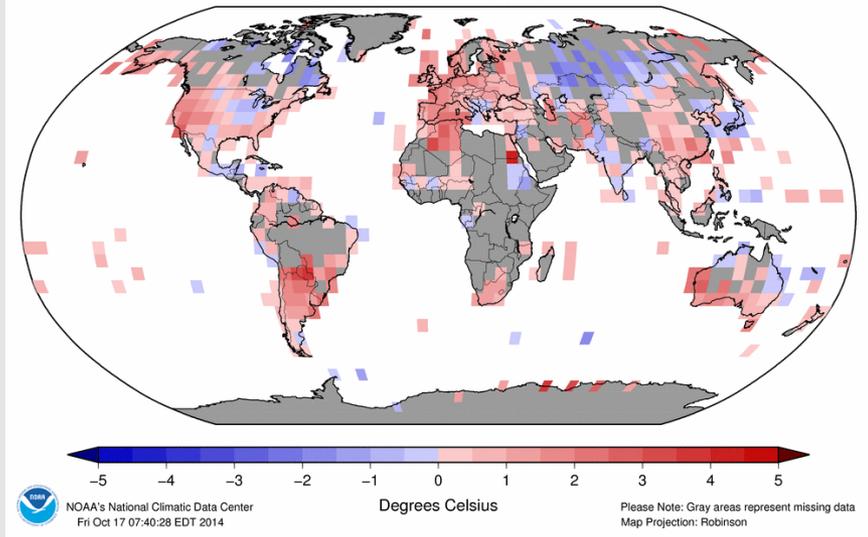
- GHCN-Monthly temperature records are combined with ocean surface temperature data for monitoring climate variability and change.

Global Land Temperature Anomalies, September



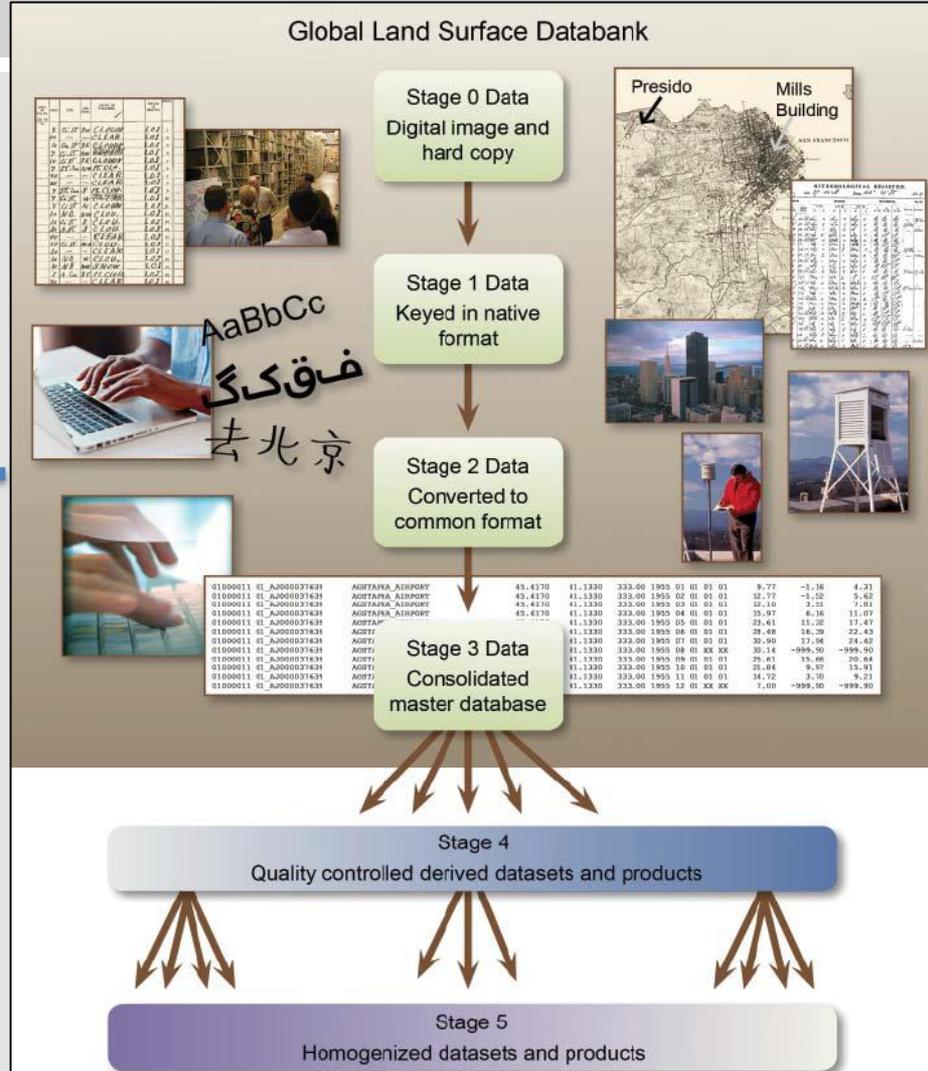
Land-Only Temperature Departure from Average Sep 2014
(with respect to a 1981–2010 base period)

Data Source: GHCN-M version 3.2.2



ISTI Databank Working Group

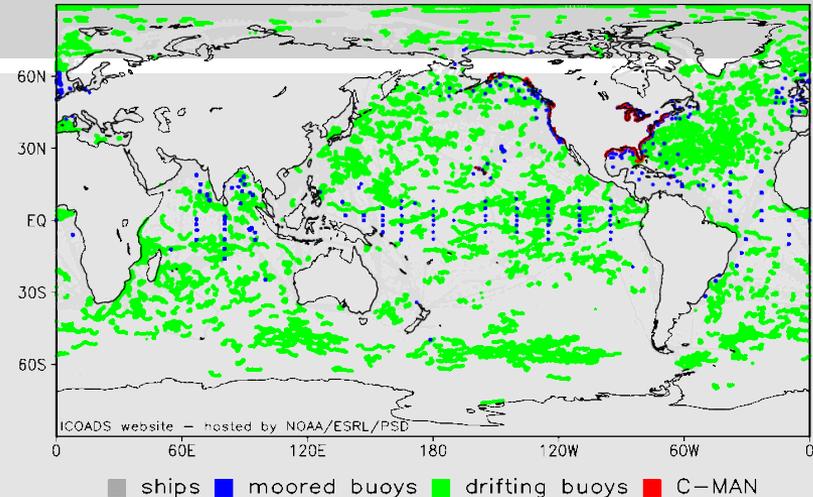
- Data provided in Stages
 - All data converted to common format in Stage 2
 - ISTI Databank responsibility ends at Stage 3
- Individual institutions can develop their own quality controlled and bias corrected datasets
- NCDC is developing a new version of GHCN-Monthly from the Stage 3 databank release



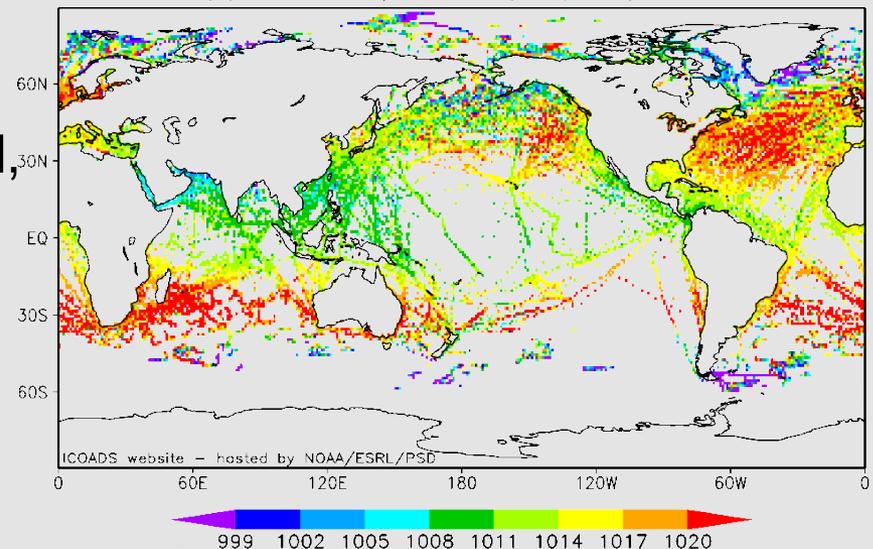
ICOADS

- Access to 290 ocean data and metadata elements including:
 - Sea Surface Temperature and Measurement method
 - Marine Air Temperature
 - Wind Direction/Speed
 - Sea Level Pressure, Visibility, Clouds
 - Wave and Swell Direction, Period, Height
 - Sea ice concentration
 - Present weather, visibility

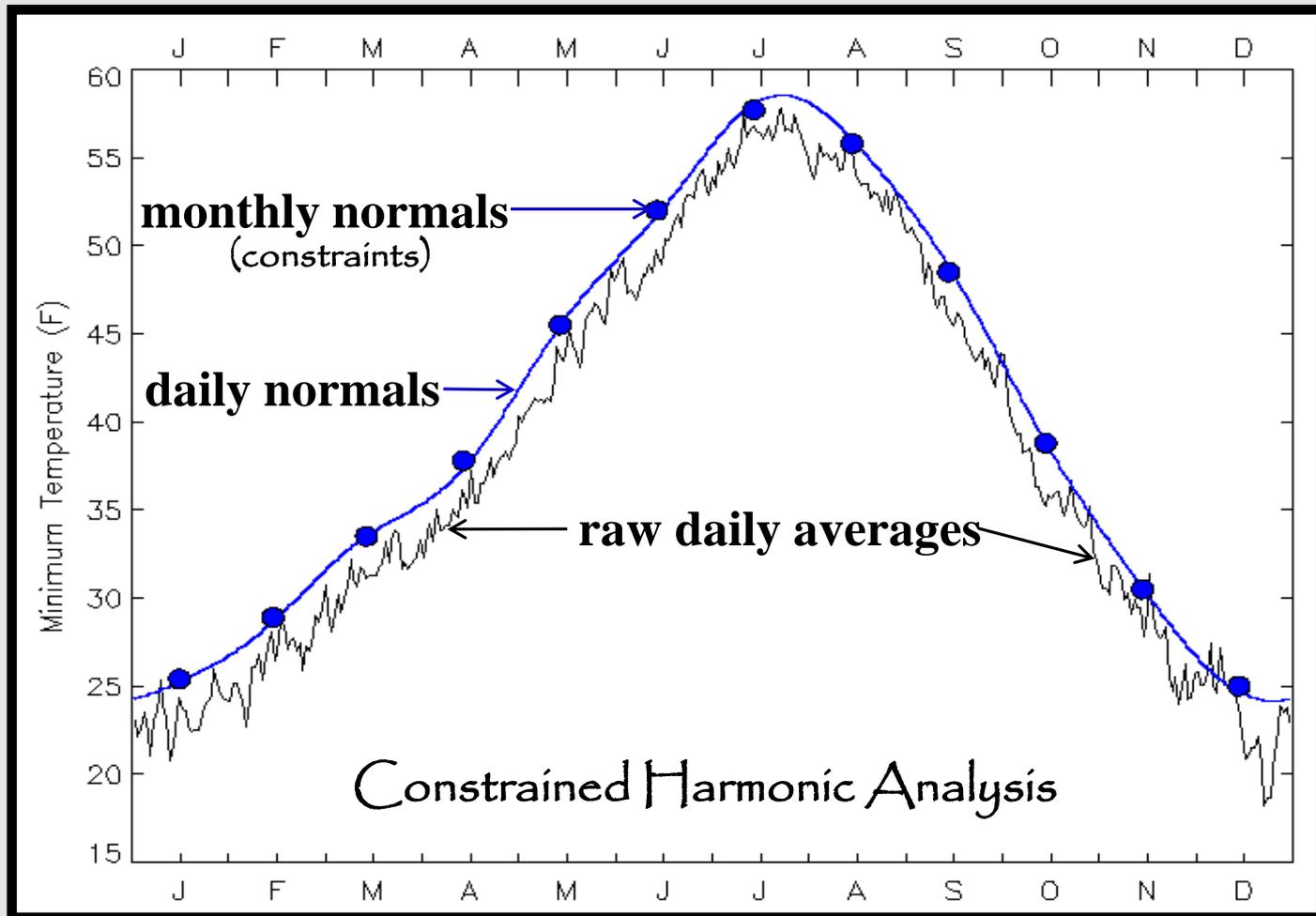
(b) map of platform mixture: Sep 2014



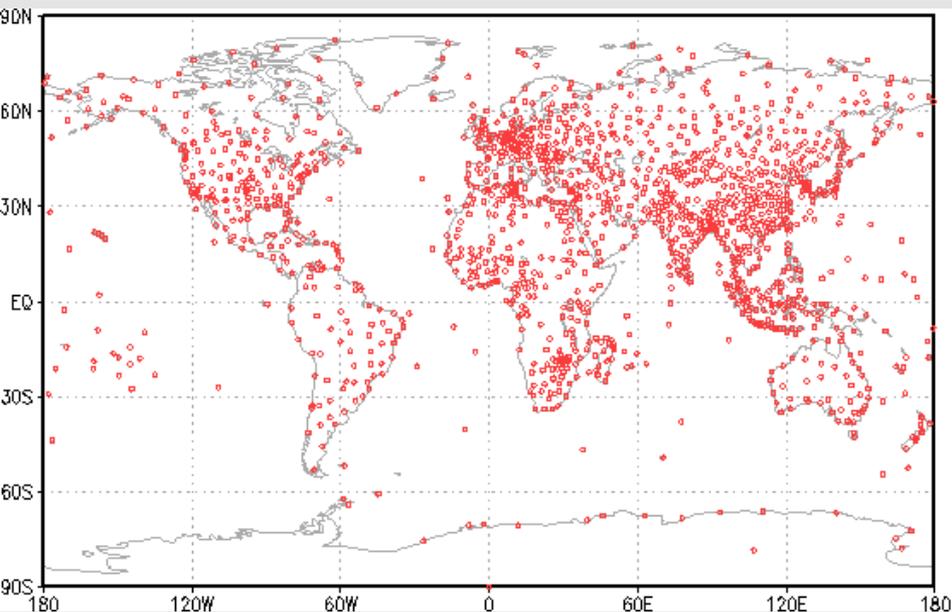
(c) sea level pressure (hPa): Sep 2014



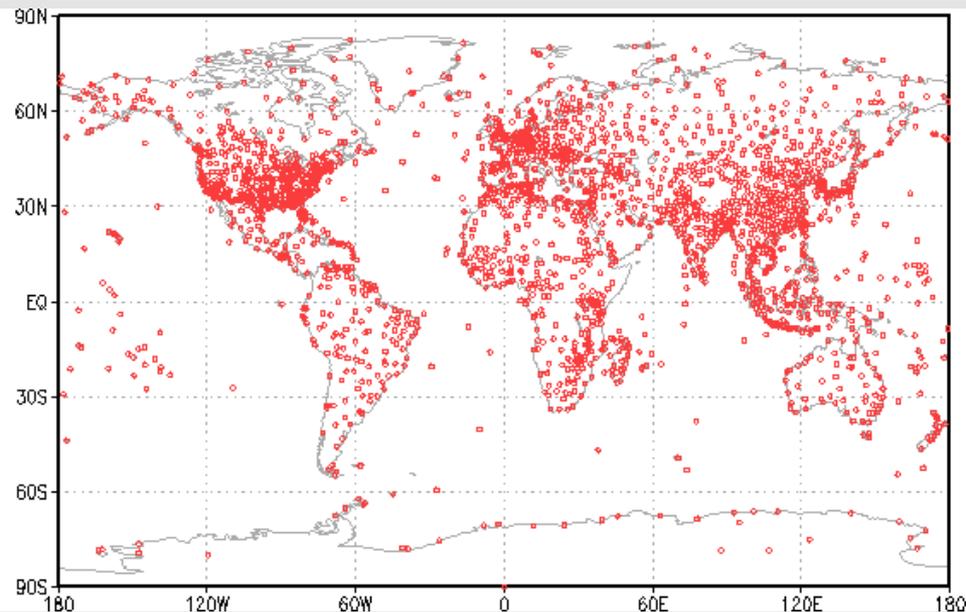
Matching Monthly and Daily Normals



Integrated Global Radiosonde Archive

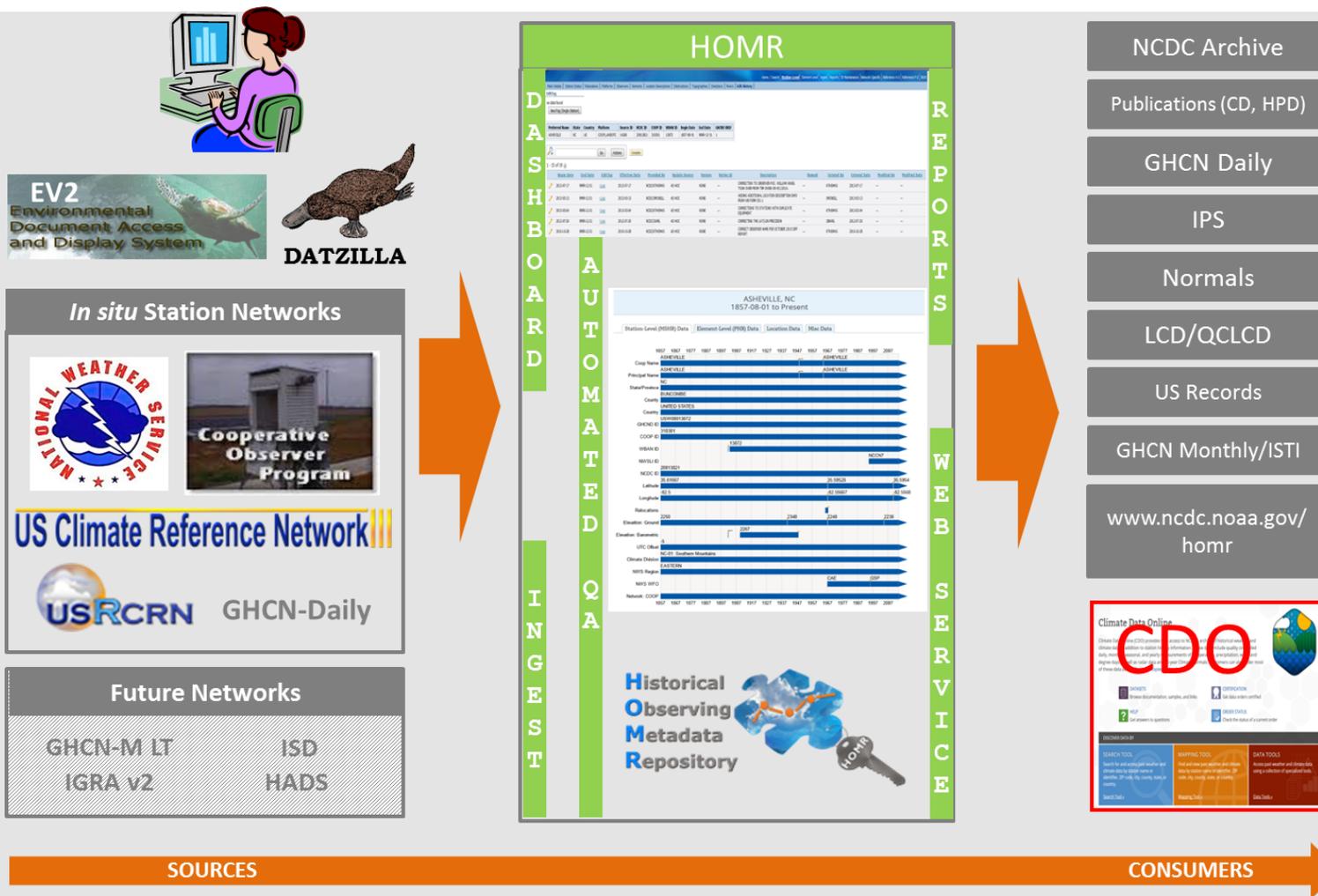


Version 1

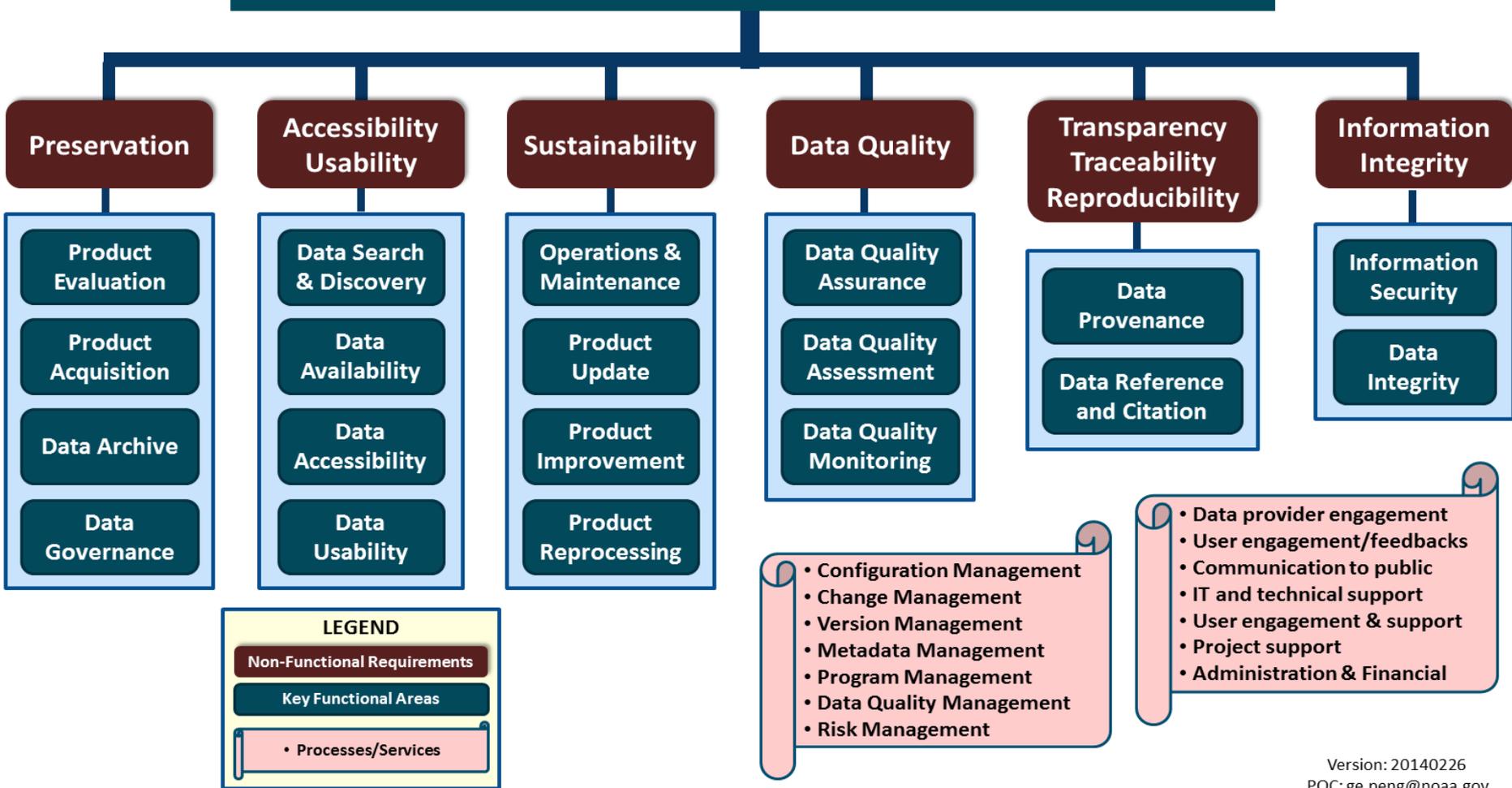


Version 2

Historical Observing Metadata Repository



Long-Term Scientific Data Stewardship



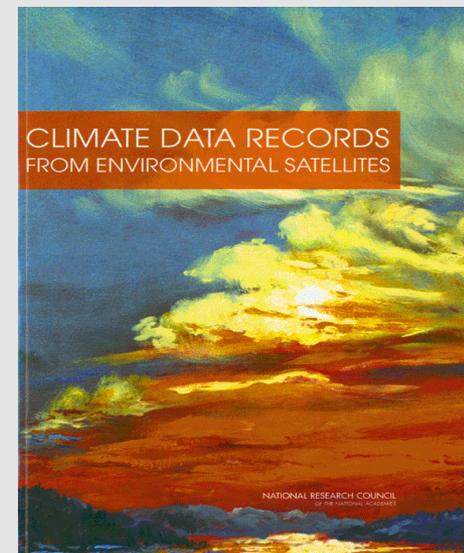
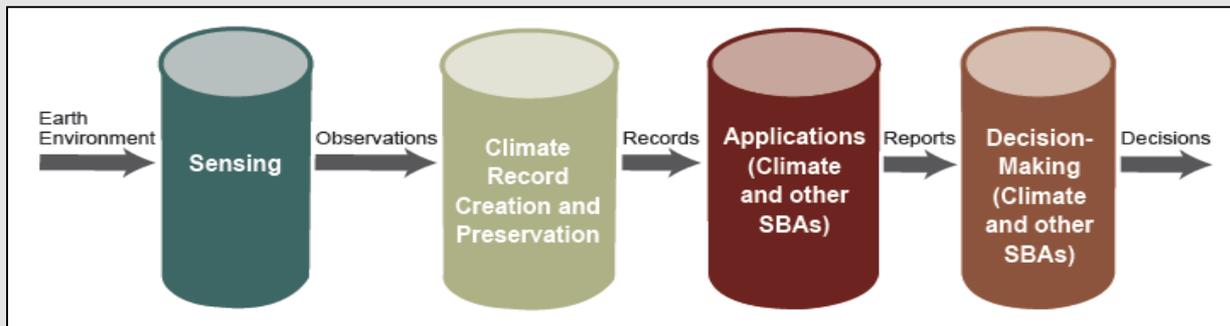
Version: 20140226
POC: ge.peng@noaa.gov

Data Stewardship

All activities that preserve and improve the information content, accessibility, and usability of data and metadata (NRC, 2007) and that ensure or improve the quality and usability of environmental data

What Are CDRs?

- “A **Climate Data Record (CDR)** is a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change” (US National Academy of Sciences, 2004)
- A relaxed definition: “...sufficient...to have societal value”?
 - **Fundamental CDR (FCDR)**: Calibrated observations for a family of sensors together with the ancillary data used to calibrate them (e.g., Brightness Temperatures)
 - **Thematic CDR (TCDR)**: Geophysical variables derived from FCDRs; may be generated by blending satellite observations, in-situ data, and model output (e.g., Sea Surface Temperature)



Sample of NOAA CDR Products

24 CDRs in Ops as of 2014

<http://www.ncdc.noaa.gov/cdr>

Sampling of Operational CDRs			
FCDR	Atmosphere	Ocean	Land
• AVHRR TOA Reflectance	• MW Mean Layer Temperature	• SST (OISST & Pathfinder)	• Surface Reflectance (AVHRR)
• HIRS Brightness Temperature (BT)	• Precipitation (PERSIANN)	• Sea Ice Concentration	• Northern Hemisphere Snow Cover Extent
• SSMI(S) BT	• Cloud (PATMOS-x)		• NDVI (AVHRR)
• VIIRS RCDR	• OLR (HIRS & GridSat)		• LAI/FAPAR (AVHRR)
• MSU/AMSU BT	• Aerosol Optical Thickness (AVHRR)		
• GOES BT (GridSat)			
Research-to-Operation CDRs (works-in-progress)			
FCDR	Atmosphere	Ocean	Land
• Solar Irradiance	• Earth Radiation Budget (ISCCP-ERB)	• Surface Fluxes	• Geo-Surface Reflectance
	• Precipitation (GPCP & CMORPH, NEXRAD NMQ/Q2 Mosaic)	• Sea Level Height	• Snow Concentration
	• Cloud (ISCCP & CERES)		
	• Ozone		

“Maturity Matrix” Defines CDR Product Readiness

Level	Sensor Use	Code Stability	Metadata & QA	Documentation	Validation	Public Release	Science & Applications
1	Research Mission	Significant changes likely	Incomplete	Draft ATBD	Minimal	Limited data availability to develop familiarity	Little or none
2	Research Mission	Some changes expected	Research grade (extensive)	ATBD Version 1+	Uncertainty estimated for select locations/times	Data available but of unknown accuracy; caveats required for use.	Limited or ongoing
3	Research Missions	Minimal changes expected	Research grade (extensive); Meets international standards	Public ATBD; Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
4 (IOC)	Operational Mission	Minimal changes expected	Stable, Allows provenance tracking and reproducibility; Meets international standards	Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions	Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood.	Source code released; Data available but of unknown accuracy; caveats required for use.	Provisionally used in applications and assessments demonstrating positive value.
5	All relevant research and operational missions; unified and coherent record demonstrated across different sensors	Stable and reproducible	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Source code portable and released; Multi-mission record is publicly available with associated uncertainty estimate	Used in various published applications and assessments by different investigators
6 (FOC)	All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny	Stable and reproducible; homogeneous and published error budget	Stable, Allows provenance tracking and reproducibility; Meeting international standards	Product, algorithm, validation, processing and metadata described in peer-reviewed literature	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation	Source code portable and released; Multi-mission record is publicly available from Long-Term archive	Used in various published applications and assessments by different investigators