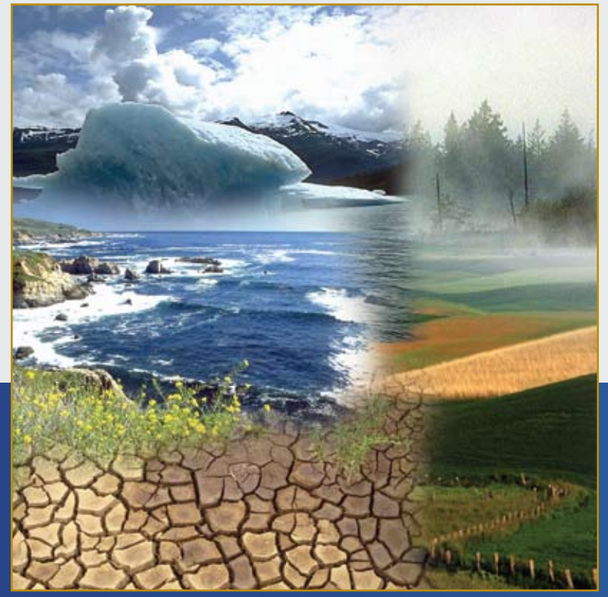
HOW CAN REANALYSIS AND ATTRIBUTION EFFORTS BE IMPROVED IN THE FUTURE?

Reanalysis

- By obtaining higher quality and more consistent observational data.
- By focusing on developing analysis methods that are optimized for climate purposes and on providing estimates of uncertainties.
- By developing the longest possible consistent record of past climate conditions to improve the description and understanding of major climate variations that occurred before the middle of the last century.
- By producing higher quality reanalysis products with better resolution, especially those products that are most relevant for applications, such as surface temperatures, winds, cloudiness, and precipitation.
- By developing national capabilities that focus on variables that are very relevant to policy and decision support. These include variables required to understand connections among the atmosphere, ocean, sea ice, and land that may lead to faster or slower rates of climate change.



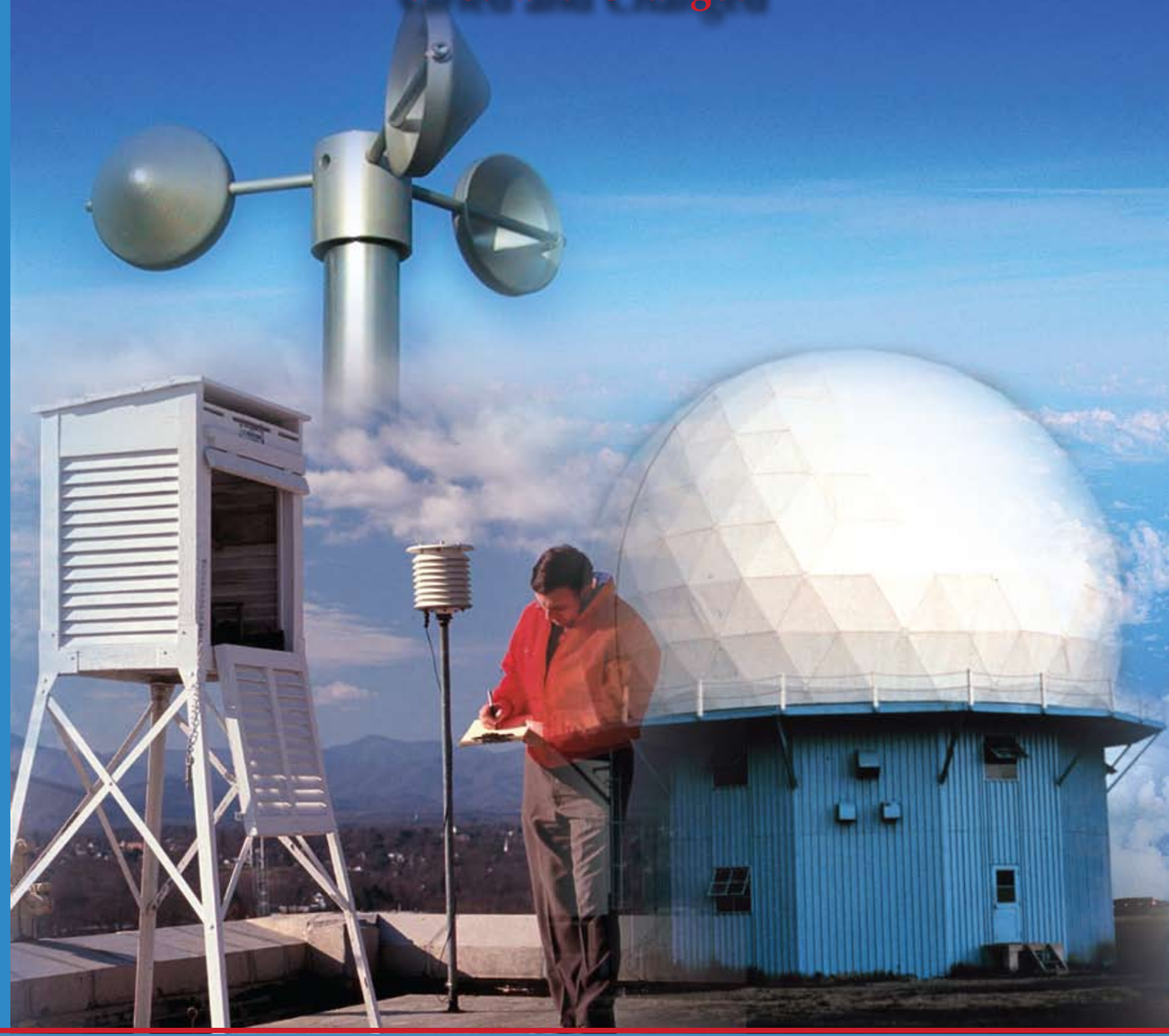
Attribution

- By developing a national capability to provide regular and reliable explanations of evolving climate conditions that are relevant to decision making.
- By better explaining causes of climate conditions at regional-to-local levels, including the roles of changes in land cover, land use, atmospheric particles, greenhouse gases, sea surface temperatures, and other factors that contribute to climate change.
- By improving methods to evaluate and communicate findings from attribution research.

By improving reanalysis and attribution methods, scientists improve knowledge of the Earth's past and present climate and environment, including its natural variations, and improve understanding of the causes of observed variability and change. These improvements will help to better answer questions from government, media, and the public about what is causing climate change.

Reanalysis and Attribution:

Understanding How and Why Recent Climate Has Varied and Changed



Findings and Summary of the U.S. Climate Change Science Program Synthesis and Assessment Product 1.3

Reanalysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Changes

Reanalysis plays a central role in determining *what* has happened in the climate system, while attribution is necessary to address the question of *why* the changes have occurred.

WHAT IS REANALYSIS AND WHY IS IT IMPORTANT?

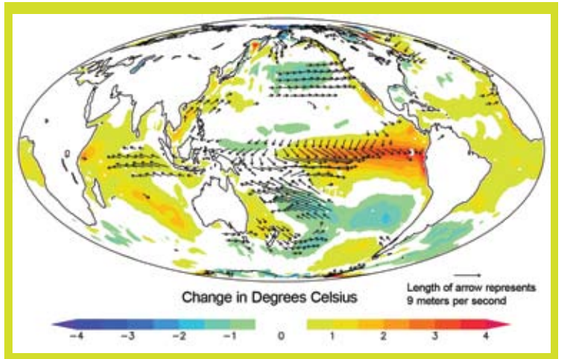
Reanalysis is a method for constructing a high-quality climate data record that combines past observations collected from many different observing and measurement systems together within a model to produce a physically consistent picture of how the Earth's climate has evolved over time.

The main goal of atmospheric reanalysis is to provide consistent and accurate records of temperatures, precipitation, winds, and many other variables that describe climate conditions from the past to the present. Values are provided for all atmospheric variables over the entire globe, extending in height from the Earth's surface up to elevations of about 30 miles. This information plays an important role in documenting how weather and climate conditions around the world are changing over time.

Reanalysis datasets are used by scientists in a variety of ways to understand complex relationships between atmospheric variables, for instance, how changes in temperatures may be connected to changes in winds, and how these in turn may be related to changes in cloudiness and rainfall. The comprehensive nature of reanalysis data is especially important for understanding the physical processes that lead to extreme climate events such as droughts and floods as well as other key atmospheric features that affect the United States, including climate variations associated with major modes of climate variability such as the El Niño-Southern Oscillation.

Information derived from reanalysis datasets is useful for a wide range of commercial and business applications in sectors such as energy, agriculture, water resources, and insurance. For example, this information can be used to analyze the supply and demand for energy, and also to evaluate locations for wind power generation. Some commonly used reanalysis products include maps showing monthly and seasonal averages, variation, and trends in temperatures, winds, precipitation, and storminess.

Some of the diverse types of observing systems that provide information used to construct a weather or climate analysis. These include satellites, aircraft, radar, weather balloons, ships at sea, offshore buoys, and surface observing stations.



A map of changes in sea surface temperatures and winds near the Earth's surface during an El Niño event, averaged from January through March 1998, compared with normal values. This map is based on the NASA/MERRA reanalysis (courtesy Derek van Pelt, NASA Global Modeling and Assimilation Office).

WHAT IS THE CURRENT STATE OF KNOWLEDGE OF REANALYSIS?

The most current reanalysis data extend back to the middle of the last century. With a few exceptions (Australia, for example), global and regional temperature trends near the Earth's surface in reanalysis datasets are broadly consistent with trends determined from other observational datasets, particularly since the late 1970s when comprehensive satellite measurements began. Reanalysis precipitation trends are less consistent with trends calculated from observational datasets. The differences are likely due mainly to limitations in the models used and the methods used to integrate the datasets within models.

Reanalysis data play a crucial role in helping to identify, describe, and understand atmospheric features associated with weather and climate variability, including high-impact events such as major droughts and floods. Reanalysis data also play an important role in assessing the ability of climate models to simulate the average climate and its variations.

The overall quality of reanalysis products varies with latitude, altitude, time period, location and time scale, and variable of interest, such as temperature, winds, or precipitation. Current global reanalysis data are most reliable in the mid-latitude regions of the Northern Hemisphere, where the United States is located. They are also most reliable for time periods ranging from one day up to several years, making reanalysis data well suited for studies of mid-latitude weather and short-term climate variations.

WHAT IS ATTRIBUTION AND WHY IS IT IMPORTANT?

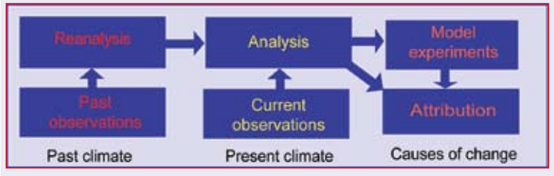
Attribution is the process of determining the most likely cause or causes for an observed variation or change in climate. It usually involves comparing observational data with results from model experiments.

Understanding the causes of climate variability and change is valuable in managing human and natural resources and for assessing risks. It is a major concern for policy makers to understand how much human-caused changes to the environment are responsible for the observed climate changes and how much is due to natural variations of climate. Resource managers, other decision makers, and the public will all benefit from understanding the causes of climate variations, such as major droughts and heat waves, because they have large impacts on society, the economy, and the environment.

New climate observations are most informative when they can be compared with past climate conditions and scientists are able to determine the causes of variations and changes.

HOW ARE REANALYSIS AND ATTRIBUTION CONNECTED?

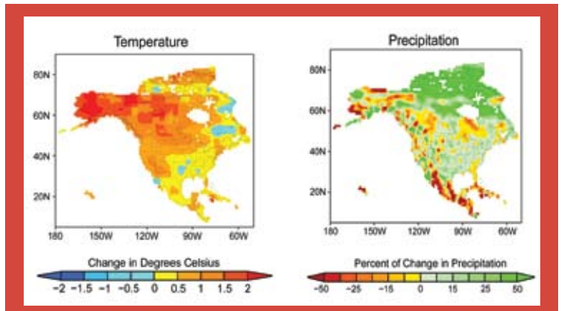
Scientists create a detailed representation of climate history that is based on past observations. From this history, changes and variations in past climates can be detected. Past and current climates can also be compared. By using reanalysis and analysis of the current climate system information, controlled experiments are conducted using climate models. The models are run several times, including and excluding factors that might affect climate, such as changes in the amount of greenhouse gases in the atmosphere or particles emitted from volcanoes. The different model results are compared and the causes of climate changes or variations can be determined. In other words, by using reanalysis information in their models, scientists can attribute certain factors that are likely or unlikely to contribute to climate variability and change. Once causes have been established, scientists are better able to project what the future climate will be like. Based on these projections, decision makers can better prepare for the future by establishing adaptation and/or mitigation strategies.



The connection between reanalysis and attribution.

WHAT CLIMATE CHANGES HAVE OCCURRED IN NORTH AMERICA SINCE THE MIDDLE OF THE LAST CENTURY?

- From 1951 to 2006 the yearly average temperature for North America increased by 0.9°C (1.6°F). Virtually all of this warming has occurred since 1970.
- Six of the ten warmest summers in the continental United States since 1951 occurred between 1997 and 2006.



Changes from 1951 to 2006 in yearly averaged North American surface temperature and precipitation based on observations.

- The largest yearly average regional temperature increases have occurred over northern and western North America, with up to 2.0°C (3.6°F) warming in 56 years over Alaska, the Yukon Territories, Alberta, and Saskatchewan. On the other hand, there have been no significant yearly average temperature changes in the southern United Sates and eastern Canada.
- There has not been a significant trend in North American precipitation since 1951, although there have been substantial changes from year to year and even decade to decade.

WHAT ARE THE CHANGES IN NORTH AMERICAN CLIMATE ATTRIBUTED TO?

- More than half of the warming averaged over all of North America is *likely* (more than 66 percent likelihood) the result of human activity.
- The regional differences in summertime surface temperature trends across North America are *unlikely* (less than 33 percent likelihood) to be the result of human activity alone. The temperature trends *likely* have been influenced by regional variations in sea surface temperature.
- The regional and seasonal differences in precipitation changes are *unlikely* to be the result of human activity alone. Some of the variations that have occurred are *likely* the result of regional variations in sea surface temperatures, which influence precipitation patterns.

WHAT FACTORS CONTRIBUTE TO HIGH IMPACT DROUGHTS OVER NORTH AMERICA?

- It is *unlikely* that a systematic change has occurred in either how often or where severe droughts have occurred over the continental United States during the past half-century.
- It is *likely* that changes in sea surface temperatures have contributed to multi-year droughts that have affected North America during the past half-century.
- It is *likely* that human activity has increased drought impacts over North America in recent decades through increased water stresses associated with warmer temperatures, but it is uncertain how large this effect has been.