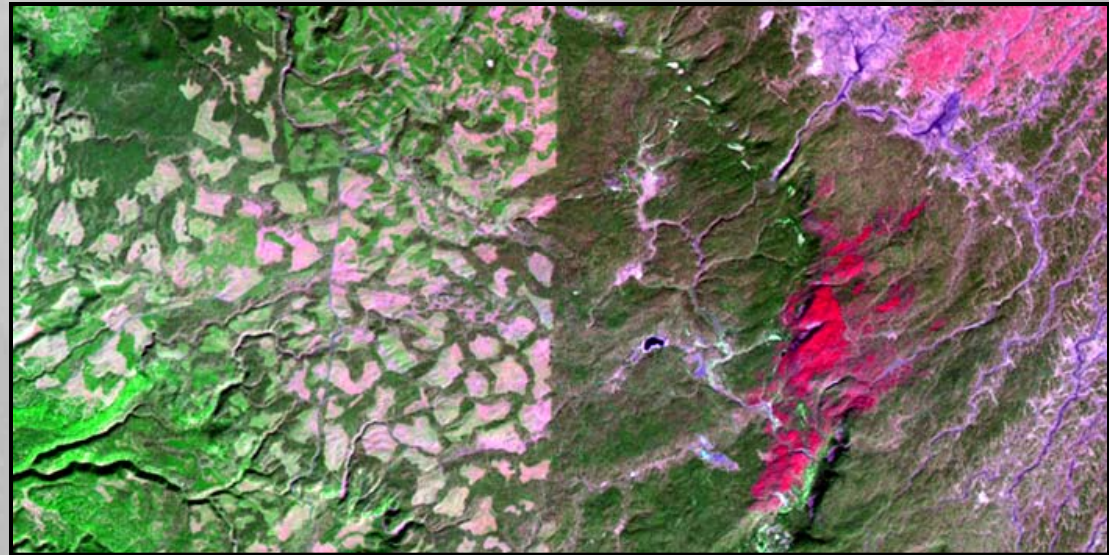


# Monitoring the Earth with 40 years of Landsat Data

Presented for the Interior  
Museum and the DOI Office of  
International Affairs  
by  
Bruce K. Quirk  
Program Coordinator  
Land Remote Sensing

July 18, 2012



Boundary between Targhee National Forest (*left*) showing forest clear cut areas and Yellowstone National Park (*right*)

# Landsat Program Foundation

1966 - Initiated Earth Resources Observation Systems Program

*“...the time is now right and urgent to apply space technology towards the solution of many pressing natural resource problems being compounded by population and industrial growth.”*

Secretary of the Interior Stewart L. Udall, 1966

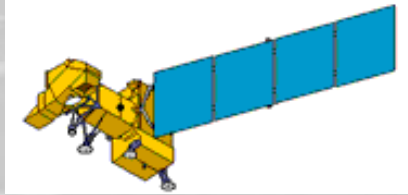
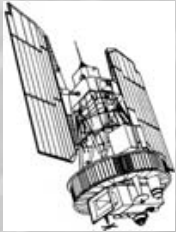




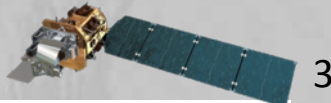
# What is Landsat?

## The World's Most Sophisticated Optical Observatories of the Earth

Landsat 1 - 3  
Multi-Spectral Scanner (MSS) 79 meter  
Return Beam Vidicon (RBV) 80/40 meter



Landsat 7  
Enhanced Thematic Mapper  
Plus (ETM+) 30/15 meter

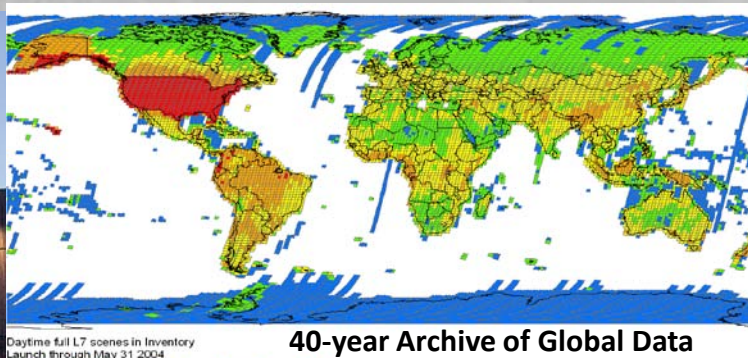


Landsat 8

Landsat 4 - 5  
Multi-Spectral Scanner (MSS) 79 meter  
Thematic Mapper (TM) 30 meter



EROS Center  
Sioux Falls, SD

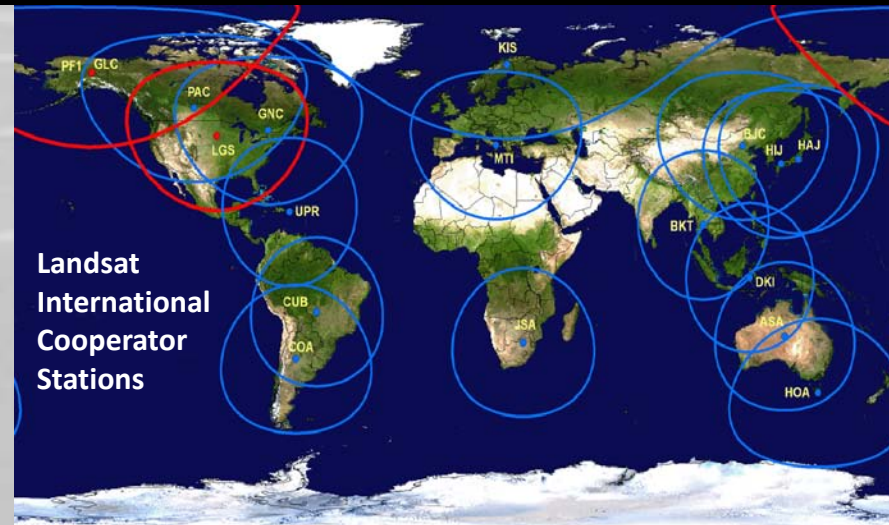


40-year Archive of Global Data



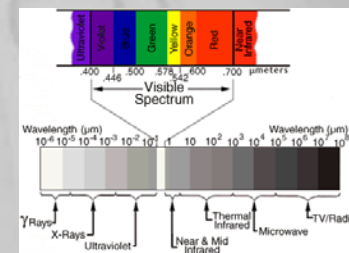
Modern Digital Silo

## The World's Model for International Collaboration in Earth Observation



# Driving the need for Landsat

- Science – understanding a changing planet
- Operational applications – managing and monitoring resources for economic and environmental quality, public health and human well-being and national security
- Require
  - A long-term continuous record of well-calibrated global land-surface change
  - Data from all parts of the electromagnetic spectrum, including thermal data
  - Data at a scale where human vs. natural causes of change can be differentiated



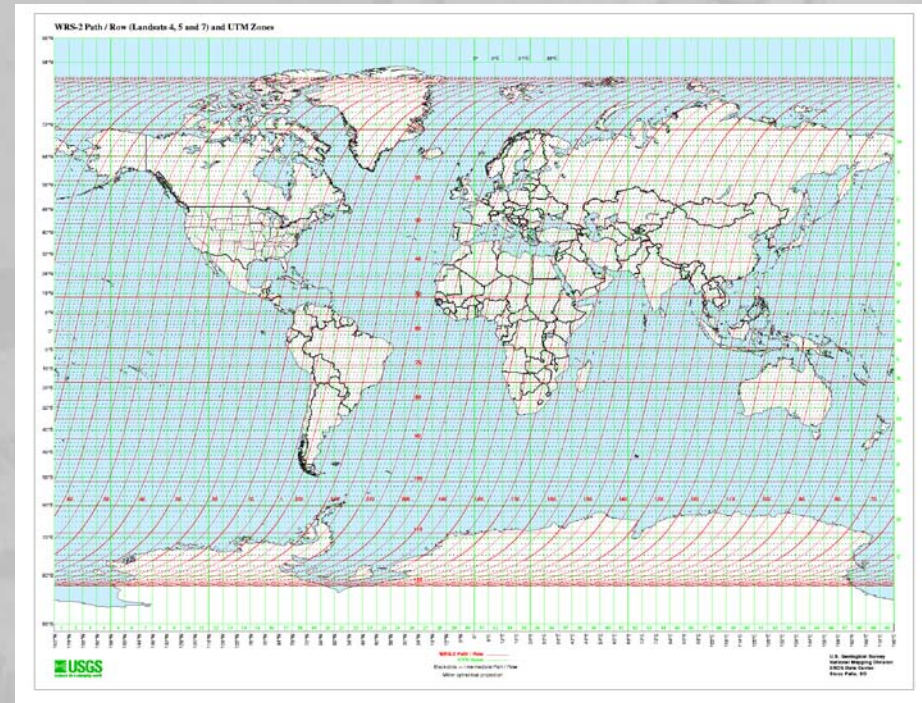
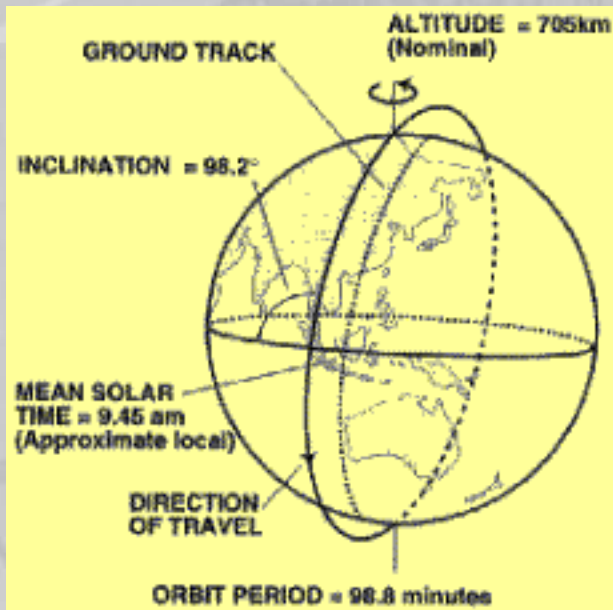
## Many Diverse Uses of Landsat data:

- |                            |                            |                           |
|----------------------------|----------------------------|---------------------------|
| • Agriculture and Forestry | • Water Resources Planning | • Land Use/Land Cover     |
| • Mapping                  | • Global Change Science    | • Famine Early Warning    |
| • Fire/Disaster Management | • Flood Management         | • Drought Monitoring      |
| • Carbon Assessment        | • National Security        | • Transportation Planning |
| • Land Use Planning        | • Ecosystem Monitoring     | • Coastal Mapping         |



# Why is Landsat so Important?

- Landsat is the only satellite system capable of acquiring cloud-free imagery of the entire globe every season of the year on a scale useful for detecting and monitoring changes to the Earth's lands
- “For more than 30 years, Landsat observations have provided the best means of examining the relationship between human activities and the terrestrial environment.” National Research Council, 2005
- Landsat is “essential for monitoring global agriculture, tracking the status of Earth's ecosystems and natural resources—including impacts of climate variability, assessing the condition of national energy and transportation systems, aiding military and intelligence operations, disaster mitigation and response, natural resource management, mapping, and many other operational applications of utility and importance to governments throughout the United States and globally.” National Science & Technology Council, 2007



# How Landsat Compares to Other Satellites

**Resolution Comparison**

**Low Resolution - 1 Kilometer Resolution**  
Advanced Very High Resolution Radiometer

**Moderate Resolution - 30 Meter Resolution**  
Landsat 7 Enhanced Thematic Mapper Plus

**High Resolution - 1 Meter Resolution**  
IKONOS Panchromatic

IKONOS imagery is provided by Space Imaging Inc.

IKONOS imagery is provided by Space Imaging Inc.

Weather and meteorological satellite imagery (>250 meter spatial resolution) is too coarse to study local details at a regional scale

Landsat's orbit, on-board systems, and ground receiving stations are optimized for studies at regional, national, or continental scales

Very high-resolution satellite and aerial imagery (<1 meter spatial resolution) is too fine to easily and affordably conduct studies of regional scale phenomena

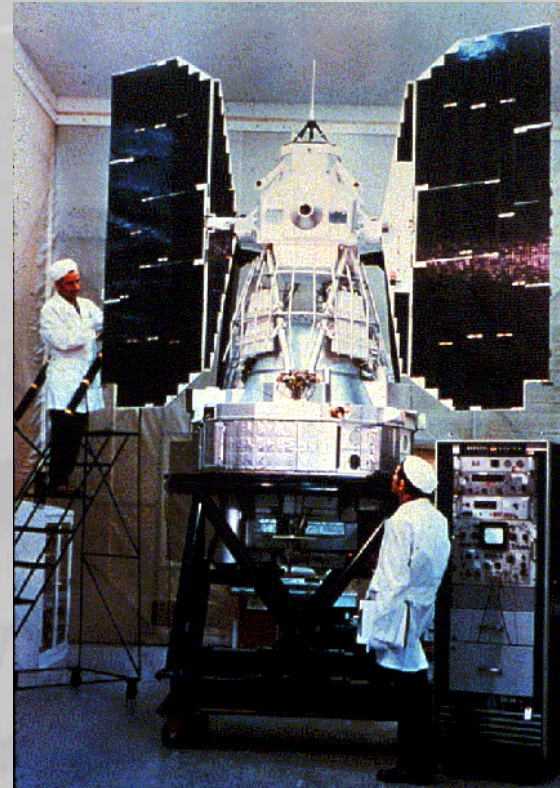
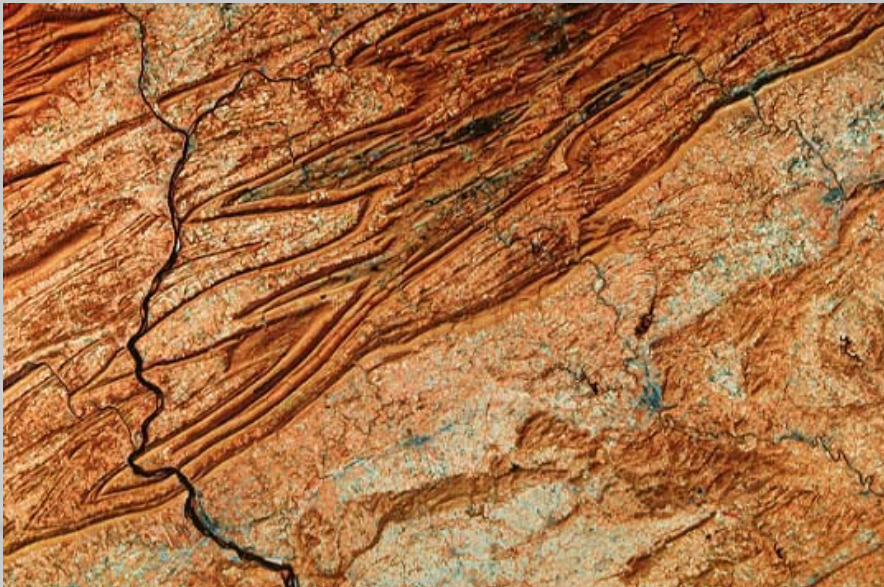
AVHRR imagery is provided by NOAA

IKONOS imagery is provided by Space Imaging Inc.

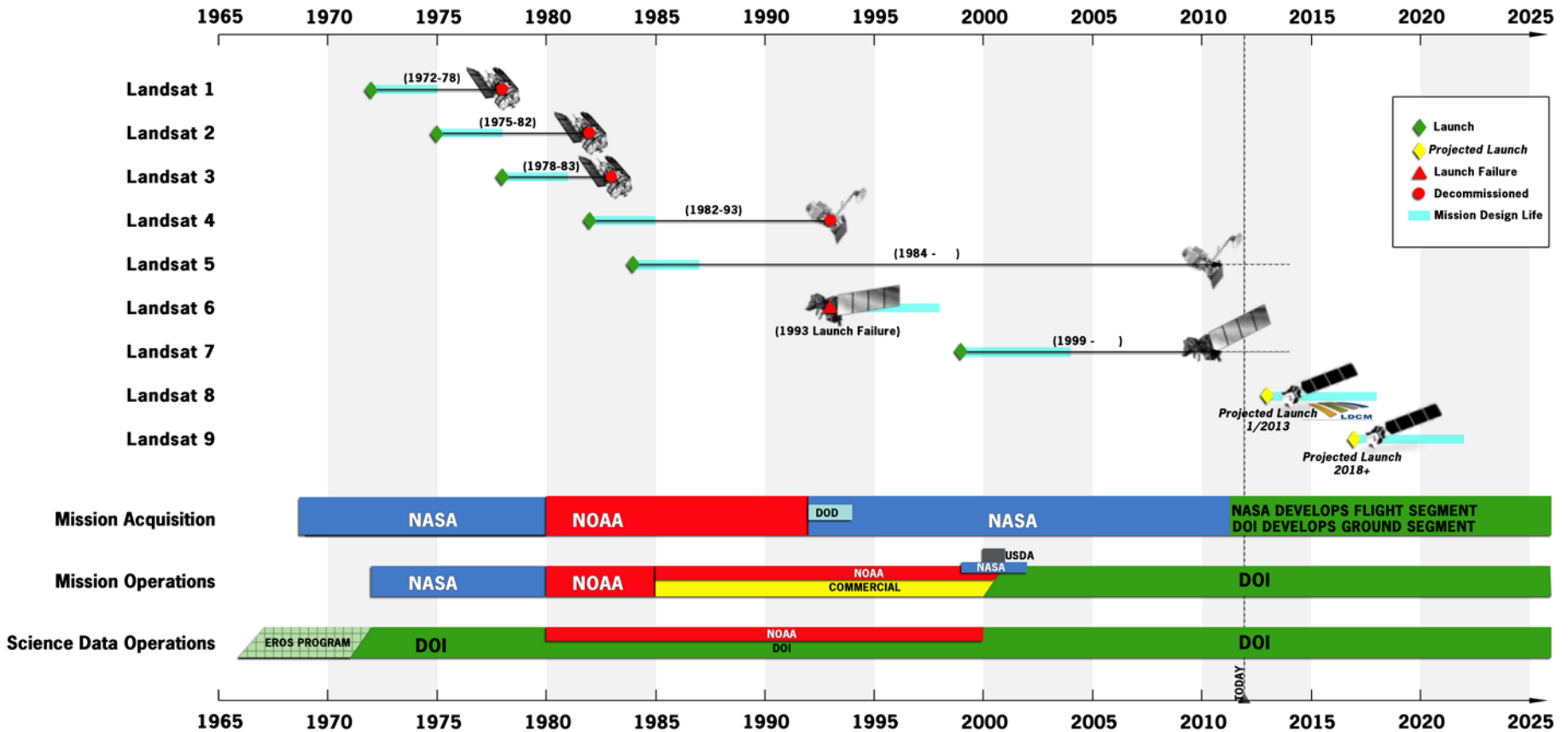


# It all started with ERTS-1

- In 1970, NASA initiated building the Earth Resources Technology Satellite-1 (ERTS-1)
- ERTS-1 was launched on July 23, 1972, starting the Landsat era
- ERTS-1 was later renamed Landsat 1

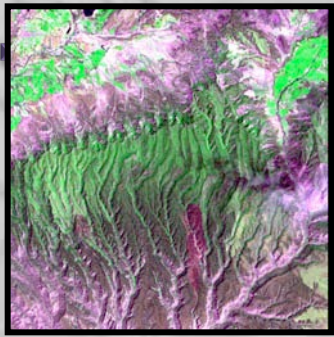


# Landsat History

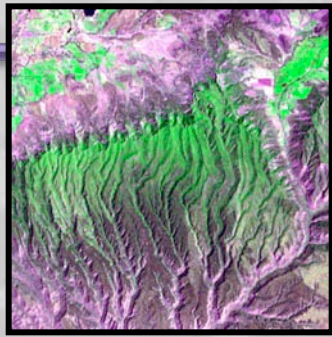




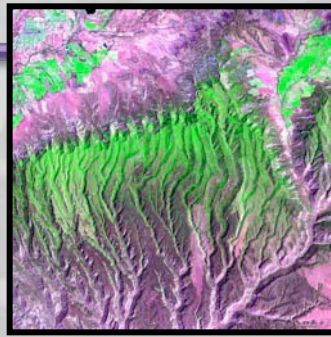
# Mesa Verde National Park, Colorado



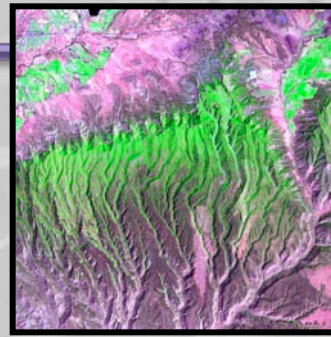
1973



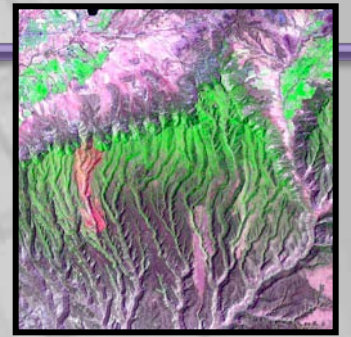
1978



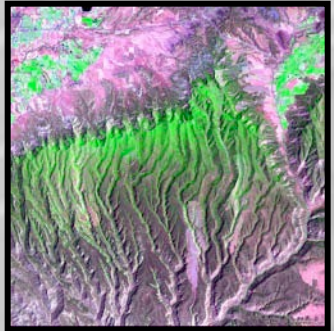
1984



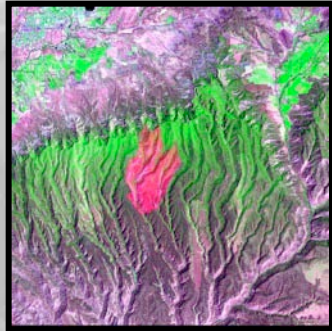
1989



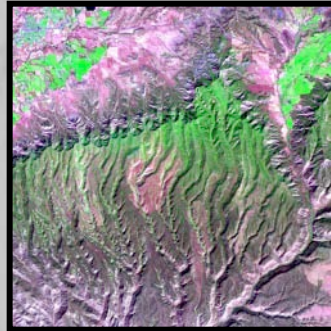
1990



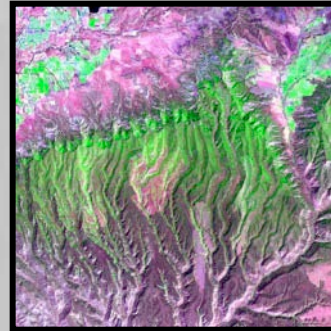
1996



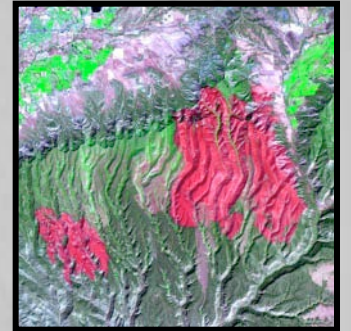
1997



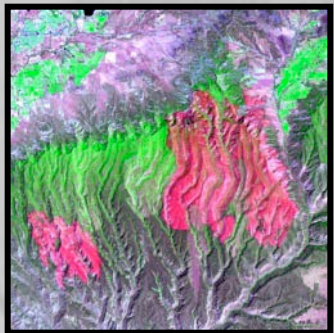
1999



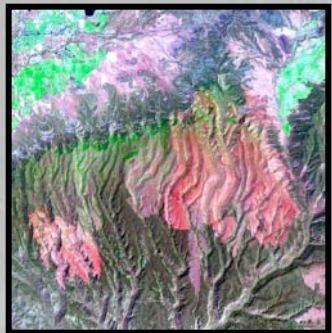
2000



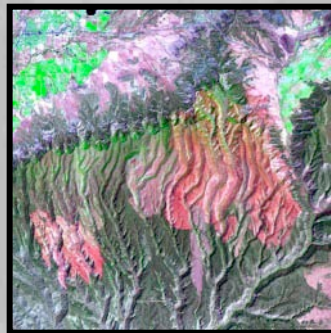
2000



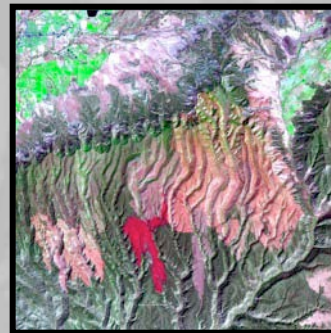
2001



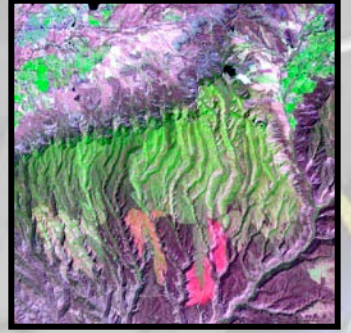
2002



2002



2002



2004

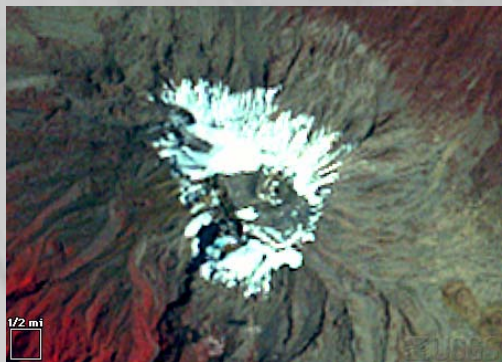
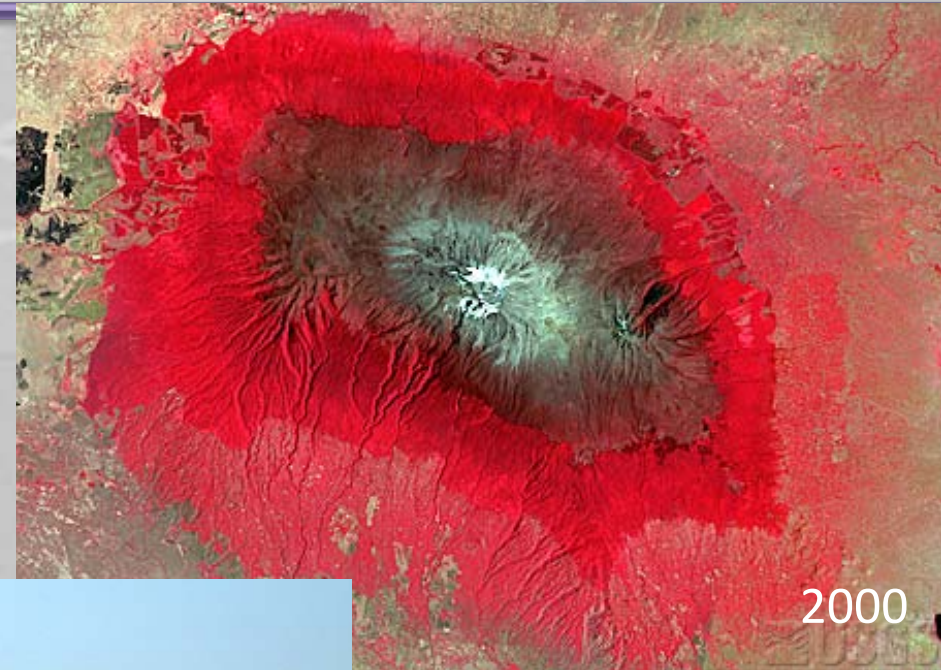


# Mount St. Helens, Washington



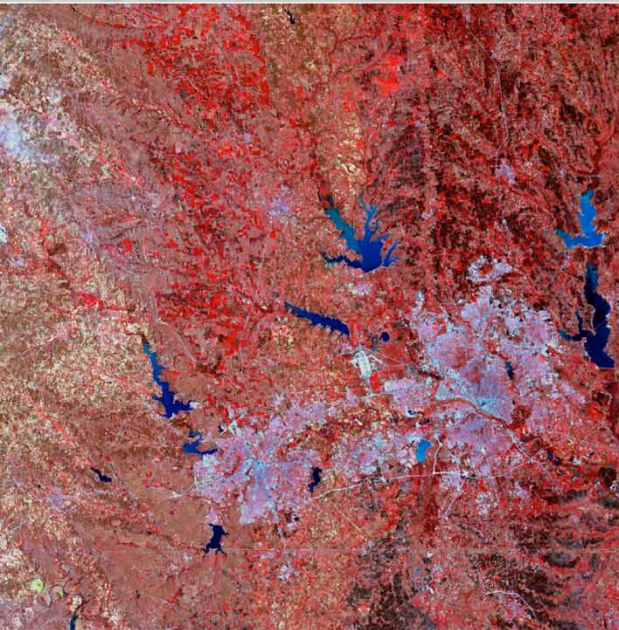


# The Vanishing Snows of Mount Kilimanjaro

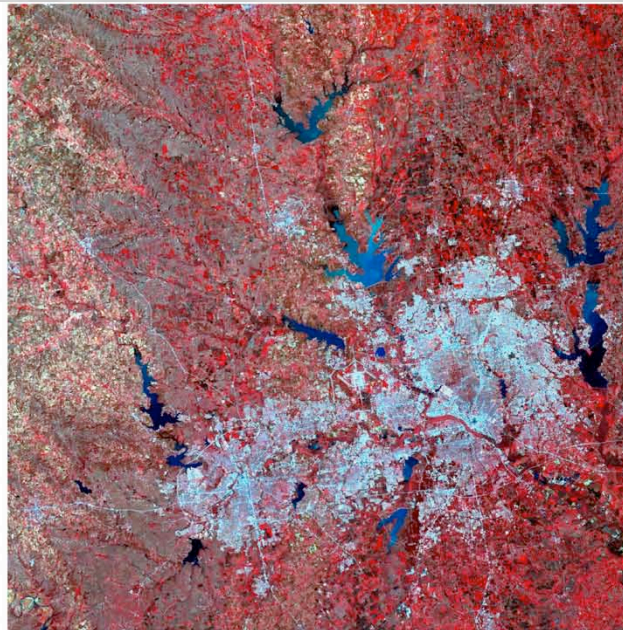




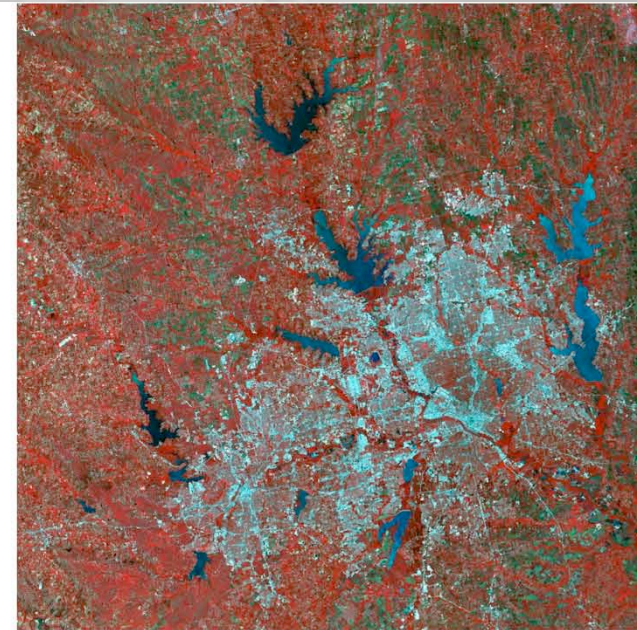
# Dallas-Fort Worth, Texas



1974



1989

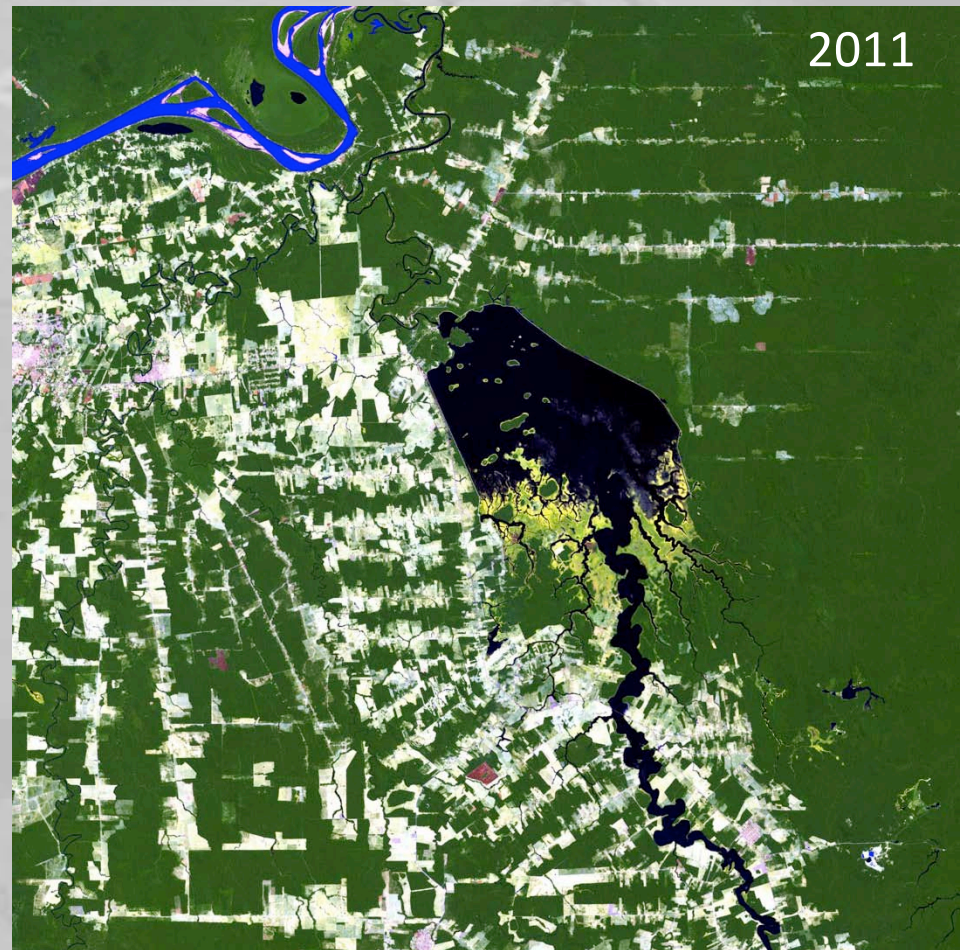
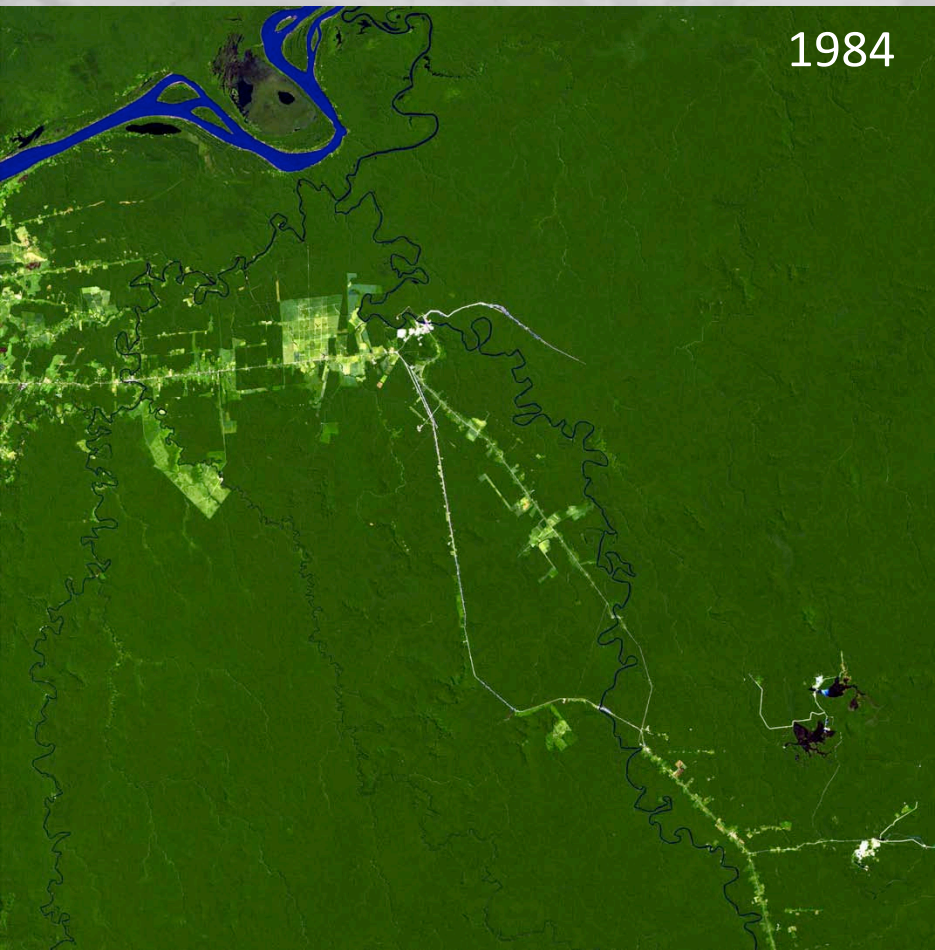


2002

The combined Dallas-Fort Worth metroplex has grown substantially, with a population of 2,378,000 in 1970; 3,776,000 in 1988; and 5,568,150 in 2002.



# Samuel Dam on the Jamari River - Rondonia, Brazil





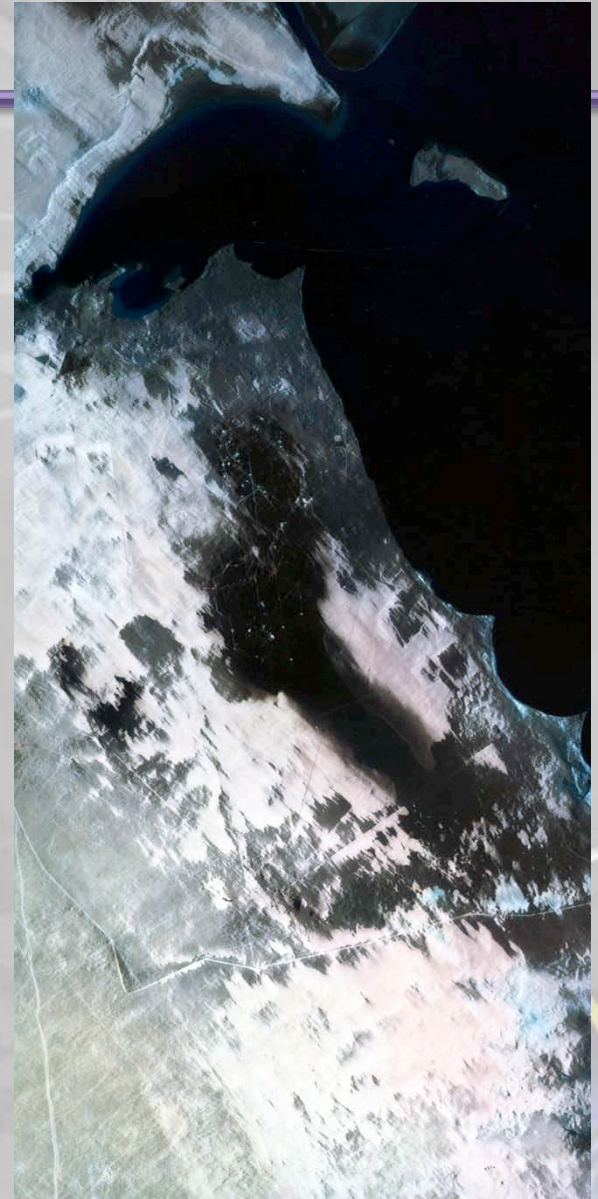
# Operation Desert Storm - 1991



Kuwait  
August 31, 1990



Kuwait  
February 23, 1991



Kuwait  
November 14, 1991

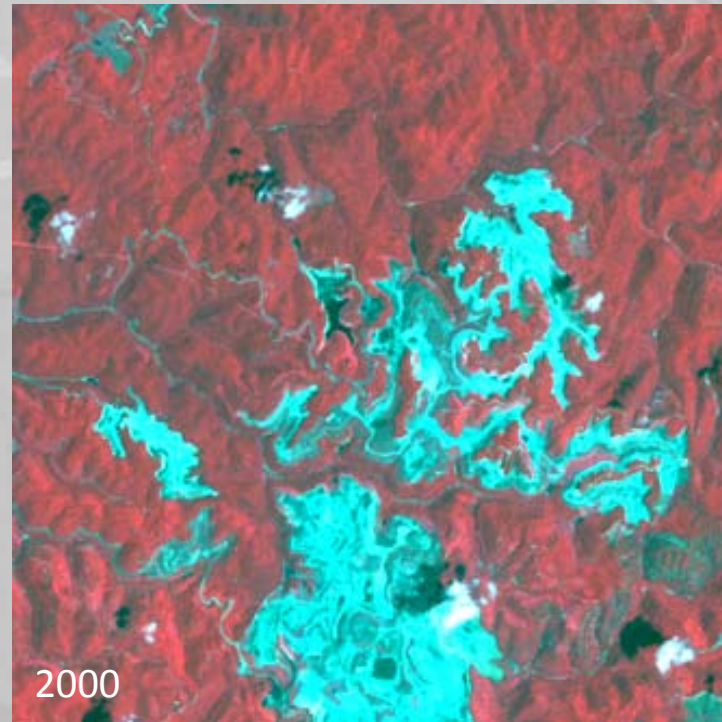
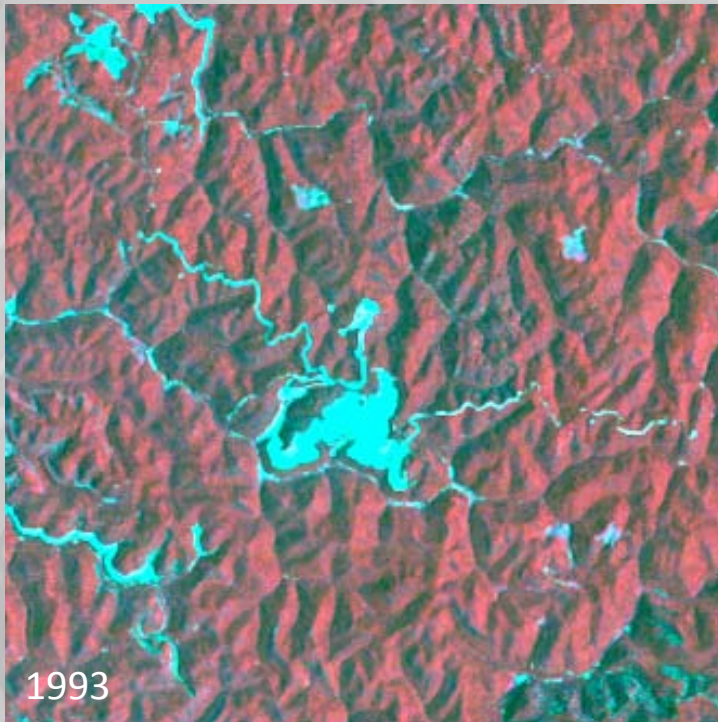


# Tornado Aftermath



Landsat 5 acquired on June 5, 2011 of Sturbridge, Massachusetts

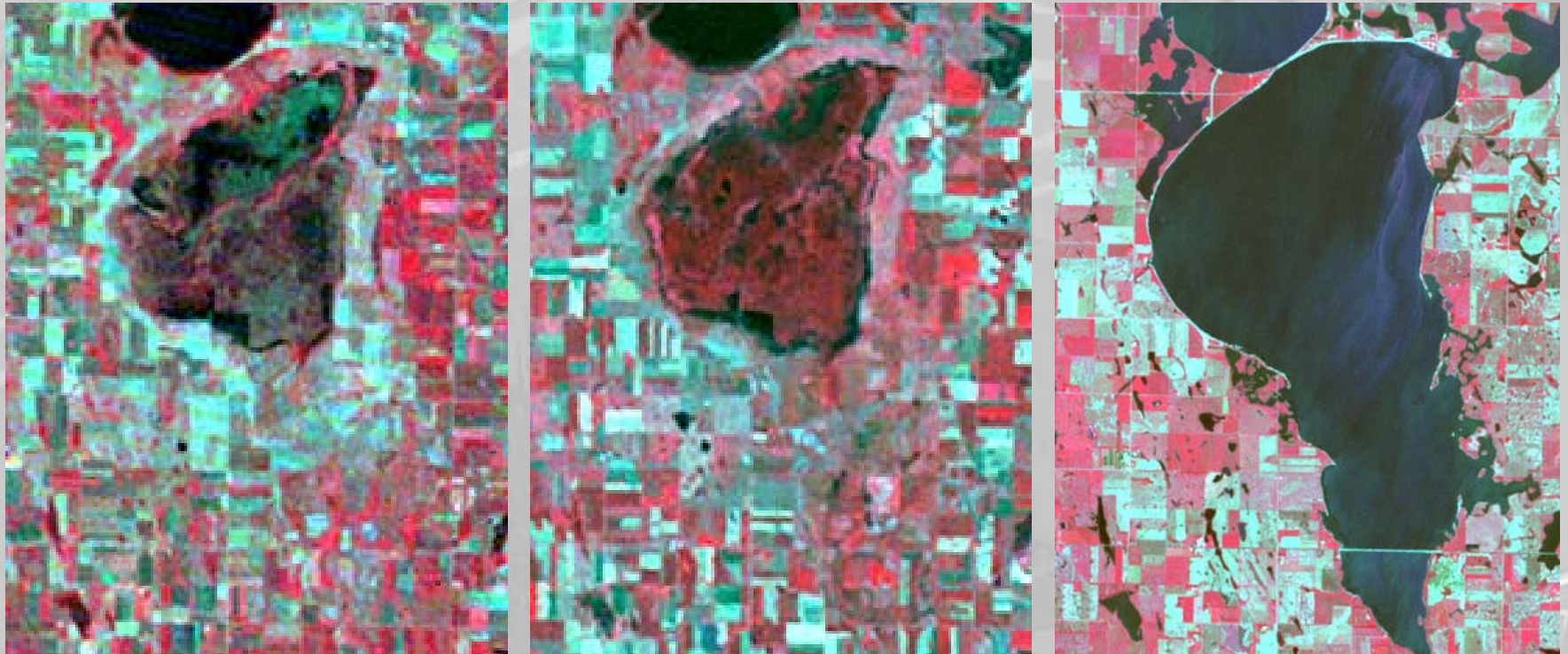
# Charleston, West Virginia Area Coal Mining



Landsat data are particularly important for environmental change research because they provide a common time series of land cover condition, starting in 1972, for Earth's land surface



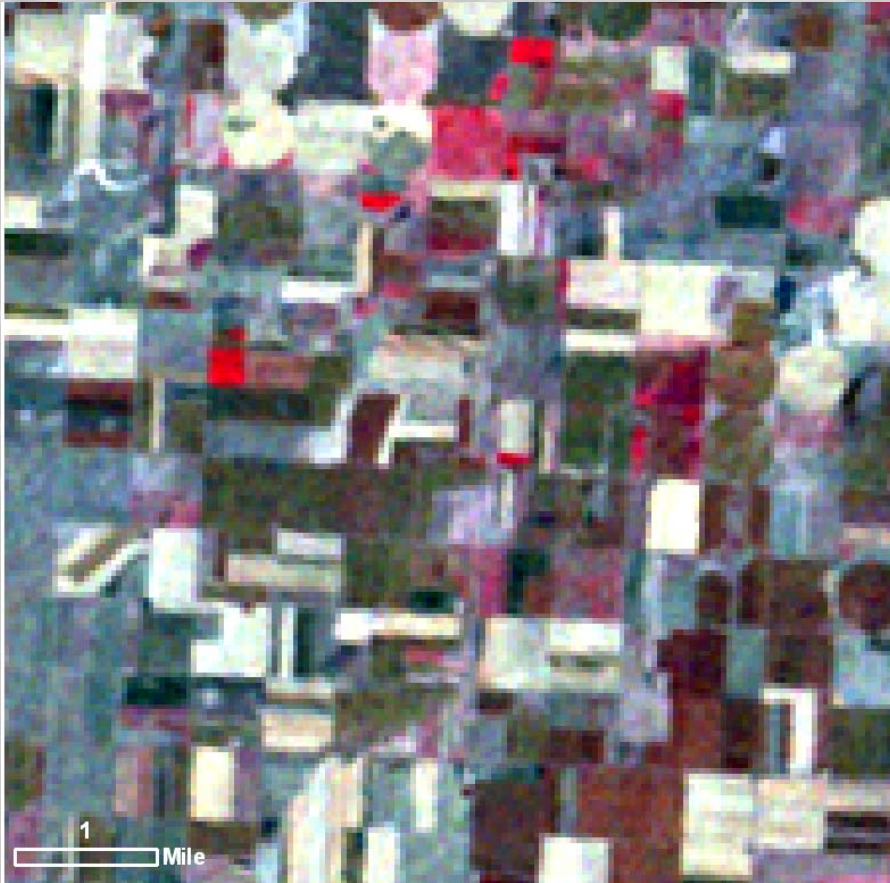
# Monitoring changes in regional hydrology



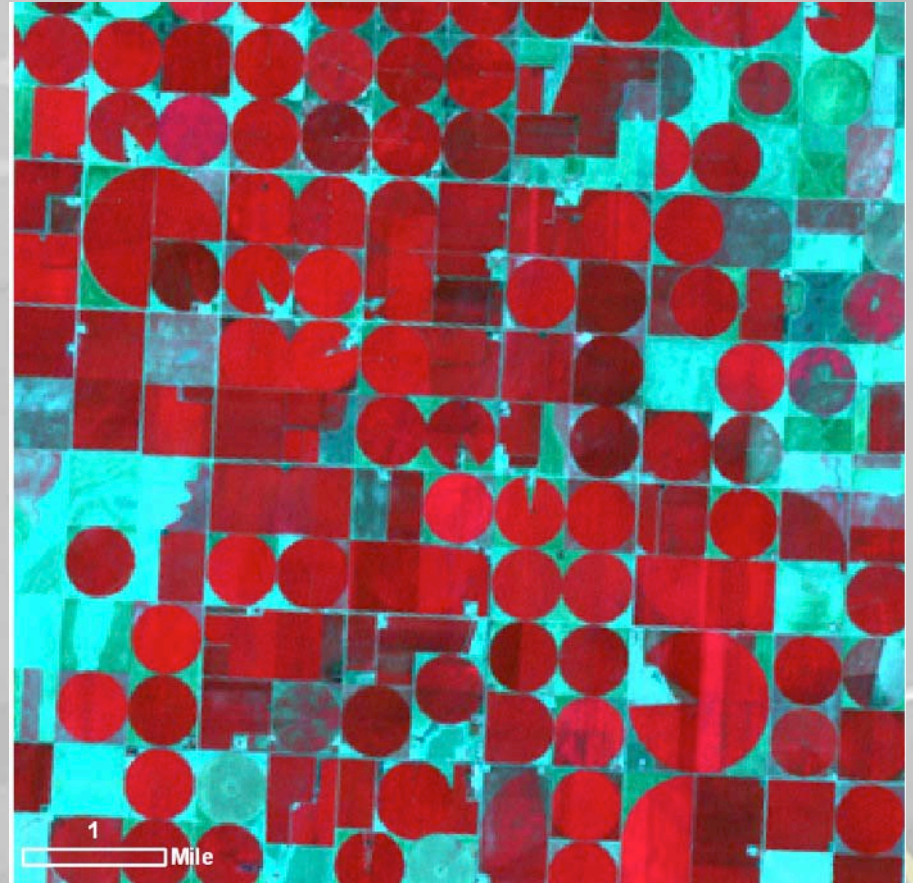
Lake Thompson, SD - 1973, 1984, 2000

Between 1984 and 2000, surface water in the Northern Glacial Plains increased by 54%

# Irrigation Expansion in Western Kansas



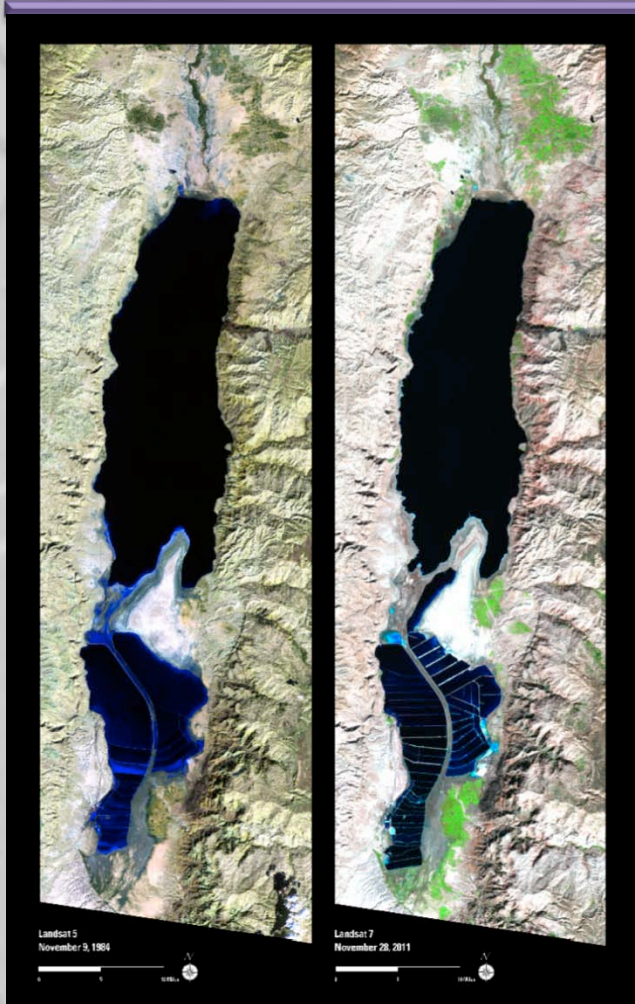
1973



2000



# The Dead Sea



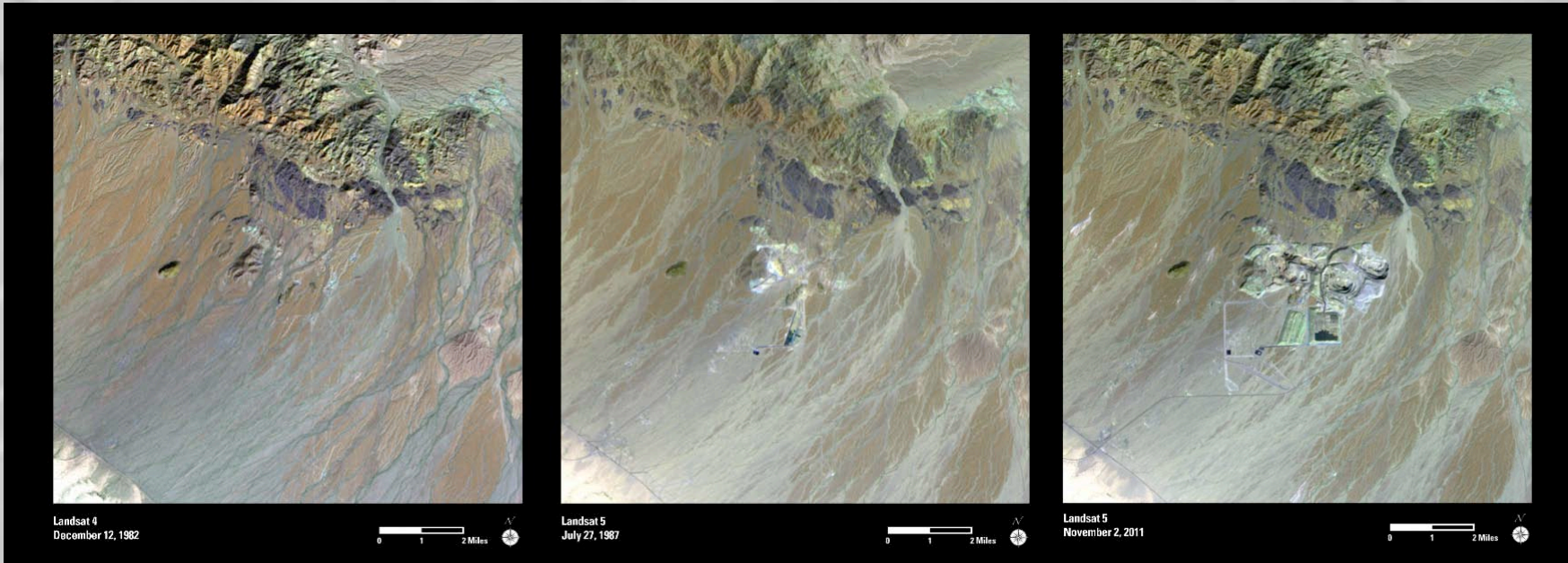
The Dead Sea is located in the Jordan Rift Valley and borders Jordan, Israel, and the West Bank. It is one of the world's saltiest bodies of water, which makes a harsh environment where animals cannot flourish. Minerals from the sea; however, are being extracted and touted as health benefit products.

These Landsat images show the change in the Dead Sea from 1984 to 2011. In recent decades, the sea has been shrinking due to diversion of water from the Jordan River, the sea's main tributary. Mineral evaporation ponds that have replaced open water in the southern part of the sea can be seen in the 2011 image.

Presently, the Jordan National Red Sea Development Project is focused on replenishing water levels of the Dead Sea by moving water along a route from the Red Sea. This will provide fresh water to Jordan, and the brine discharge will replenish the Dead Sea. To help the restoration of the sea, industrial activities may be reduced, and strict environmental measures and conservation efforts will be put into place.

Landsat imagery is useful to continually monitor the water levels and help decision makers determine the best course of action.

# Mesquite Mine, California



Gold mining in California dates back over 200 years and has been an important industry for the state. The Mesquite Mine was established in 1957 and expanded in 1986 as gold prices climbed and the mine is now one of the largest gold mines in the country. While geologists anticipated the mine's gold would be exhausted by 1999, improved extraction methods have kept the mine in production.

The mine is in the Mojave Desert, surrounded by a frail ecosystem. Consequently, the gold extraction methods, using

cyanide washes, are carefully monitored using field samples, aerial photography, and satellite imagery. Additionally, plans are underway for a major landfill to collect waste products shipped from Los Angeles, 200 miles away. The landfill will be adjacent to the mine operation, increasing the need to monitor land use changes.

Landsat imagery acquired in 1982, 1987, and 2011 show the growth of the mine and the imagery provides an important tool for monitoring regional development.



# Binhai New Area, China

Located on the coast of the Bohai Sea Region, the Binhai New Area has quickly become a major industrial center in China. The area southeast of the capital of Beijing, once home to salt farms, reed marshes, and wasteland, has become one of the country's key economic areas. The decision to develop the area began in the 1990s, and to date, the bay area is home to numerous aerospace, oil and chemical, and other manufacturing industries.



The development will include an international airport in the coming years. The changes over 20 years can be seen in these Landsat images acquired in 1992 and 2012. Landsat imagery are used to study land use change along the shorelines, and to assist regional authorities in monitoring the associated effects to water bodies and ecosystems.

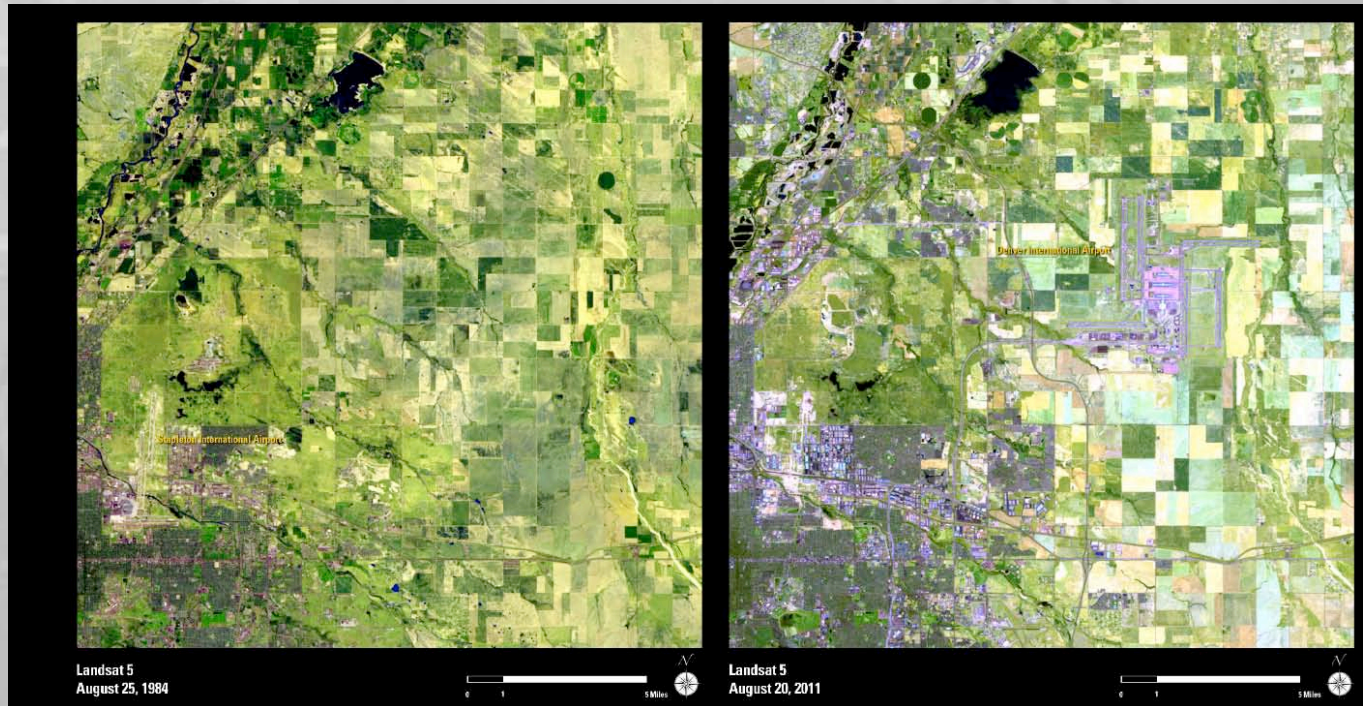
# Denver International Airport

A new airport was authorized for the Denver, Colorado, area in 1989. In 1995, the Denver International Airport officially opened and replaced the Stapleton International Airport servicing the Denver region.

Landsat satellite data illustrate the changes in the area from before the construction and after the new airport was completed. Denver International Airport covers 53 square miles, making it the largest airport in the United States and the third largest in the world.

Located 25 miles from downtown Denver, it is the 10th busiest airport in the world.

The completion of the airport has had a significant effect on the immediate area. Hotels, manufacturing, and residential



development have expanded, covering previous farm land. The growth has had a major impact on tax revenues and population needs for the Aurora, Colorado, community.

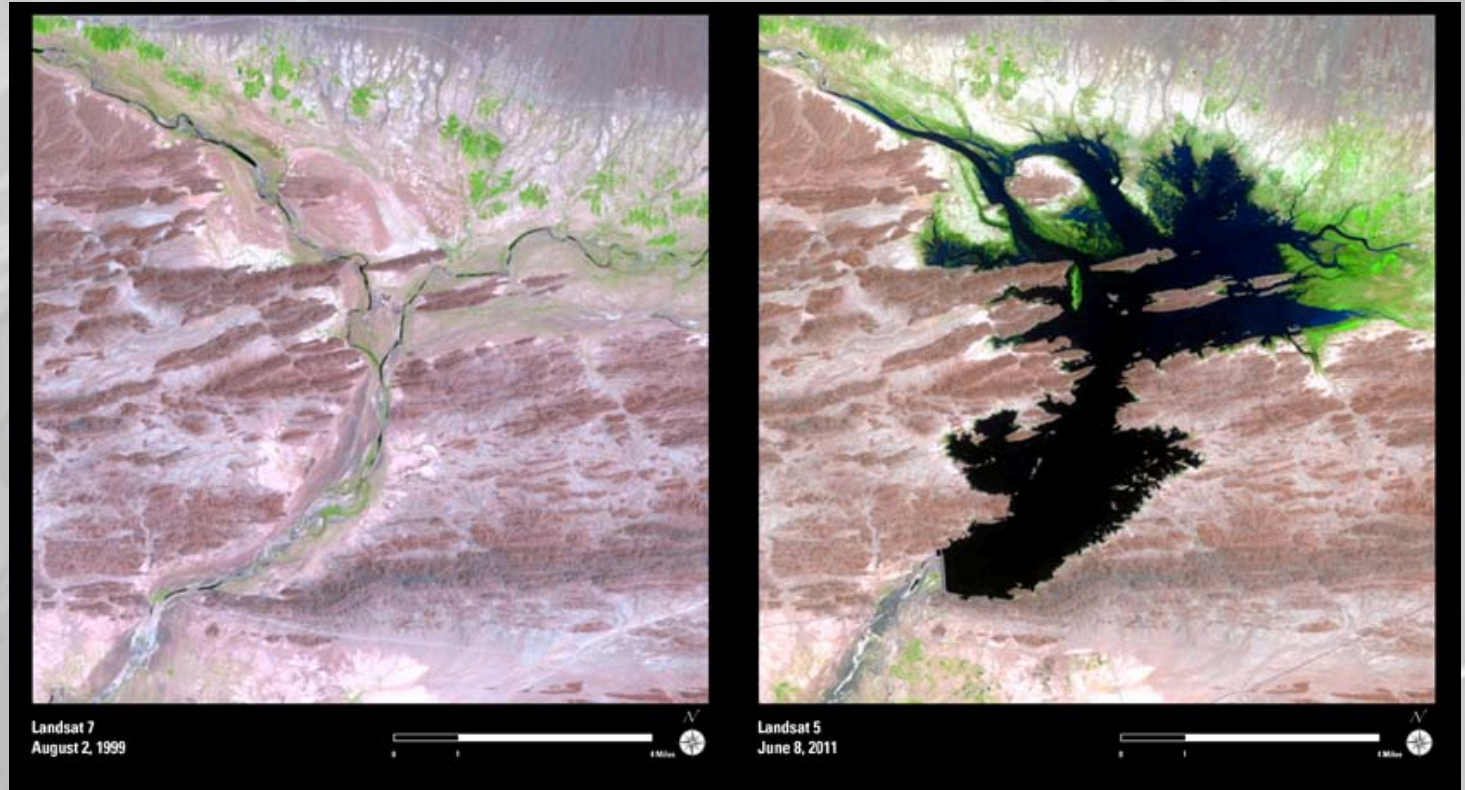
The Landsat data are used by regional and local officials to monitor the rate and direction of the expanded development caused by the siting of the airport.



# Mirani Dam, Pakistan

The Mirani Dam is located on the Dasht River in southern Pakistan. Completed in 2006, the dam created a reservoir with a depth of 244 feet. The reservoir provides water for irrigation, clean drinking water, hydroelectric power, and flood control.

Though the dam provides a constant supply of water for irrigation and human consumption, heavy rains in 2007 raised the reservoir to 271 feet, and over 15,000 people were displaced when a number of small communities were flooded. Legal actions are in process to help the displaced citizens and to adjust the water levels.



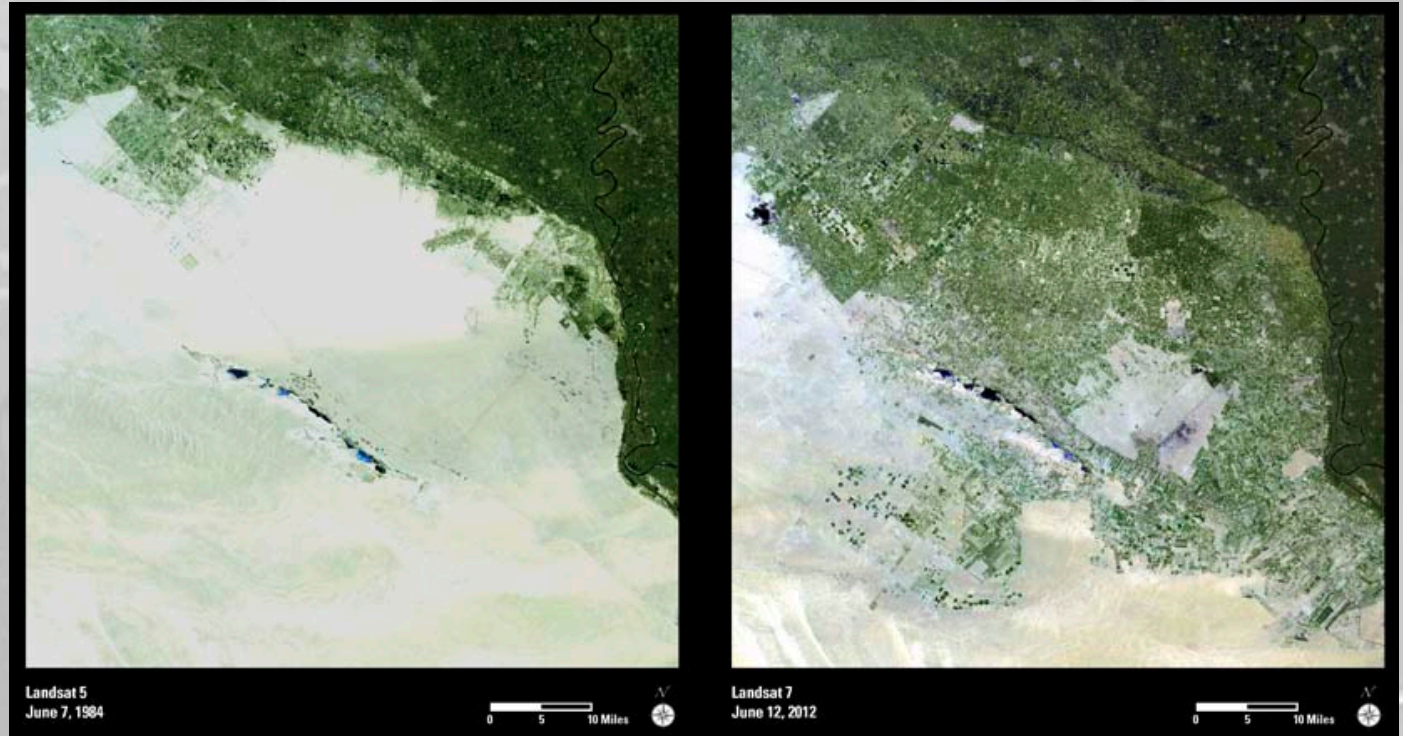
Landsat images show the Mirani Dam area in 1999 and 2011. The images show the development of the reservoir and the expanded agricultural activities in the region, activities supported by the irrigation resources provided by the dam.



# Agriculture Transforms Egyptian Desert

The Natron Valley is a natural depression of salt flats in the western desert of Egypt, northwest of Cairo (seen above as blue features in the center of the images). Ancient Egyptians extracted Natron salt from the shallow lakes for mummification purposes. This desolate area, considered a sacred region, became a sanctuary for the desert peoples and for cenobitic monastic communities.

Over the years, agricultural areas have begun to move from the fertile soils of the Nile River, which is to the east. While most fields are irrigated by water from the Nile, high water tables have allowed the use of groundwater to support additional vegetable crops.



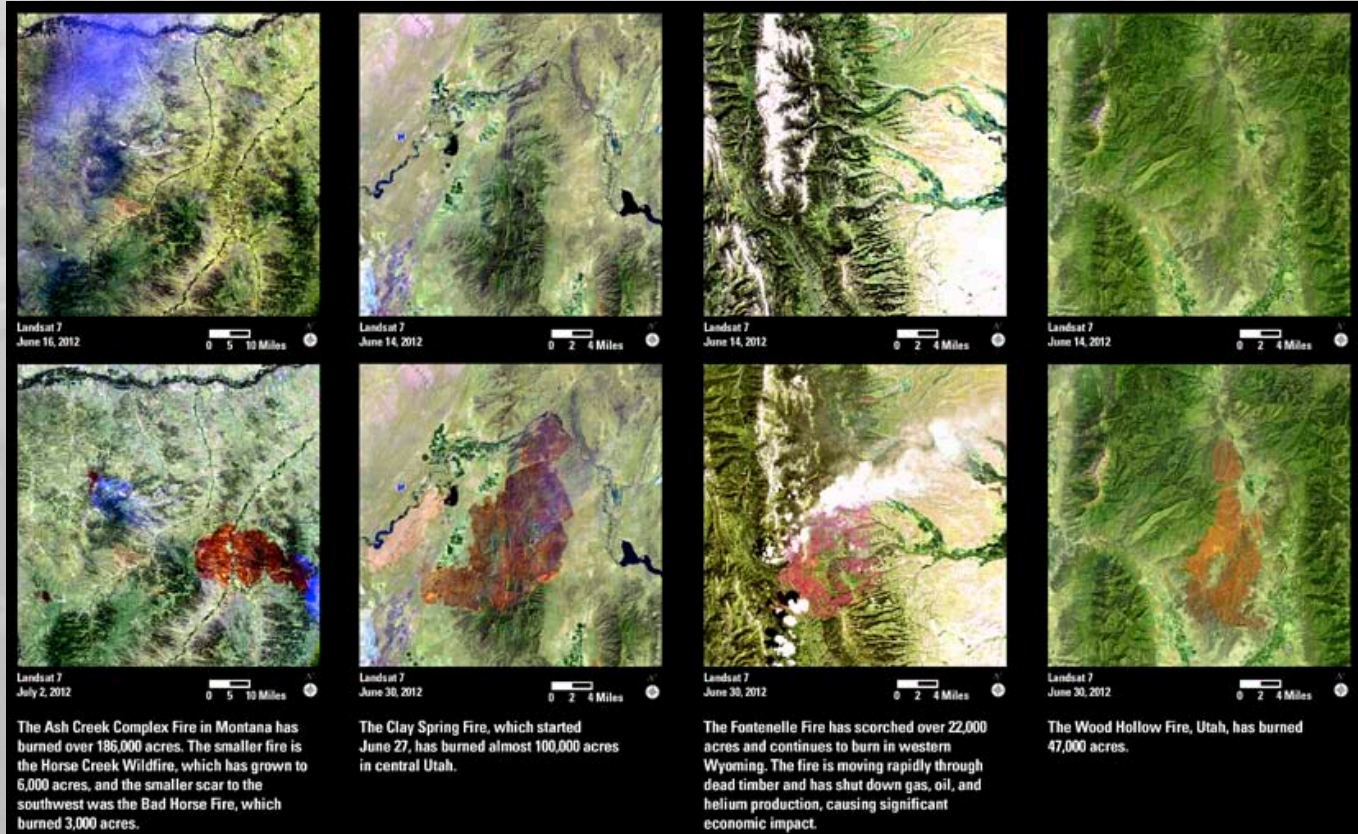
These Landsat images, acquired in 1984 and again in 2012, show in green the expanding agricultural areas. Forty years of Landsat imagery can show change over time and are useful to decision makers and others interested in the Earth's changing surface.



# Western Wildfires

Wildfires are doing severe damage in a number of western U.S. states. Extremely dry conditions, stiff winds, unusually warm weather, and trees killed by pine bark beetle outbreaks have created a situation in which major fires thrive. 52 active fires in a number of states have destroyed over 900,000 acres. Since the beginning of 2012, 27,000 fires have destroyed 1.9 million acres.

The immediate impact is loss of property and lives. Longer term, the exposed soil profiles, especially in steep-sloped regions, will affect erosion, make the areas vulnerable to potential flooding, and affect water quality.



Landsat satellite data are being used to record the rate of burning, extent of damage, and the results of efforts to control the burns. The data will be used by resource managers to monitor regrowth and rehabilitation after the fires are controlled.

The above examples illustrate the effects of fires in Montana, Utah, and Wyoming.

# Who Uses Landsat Data?

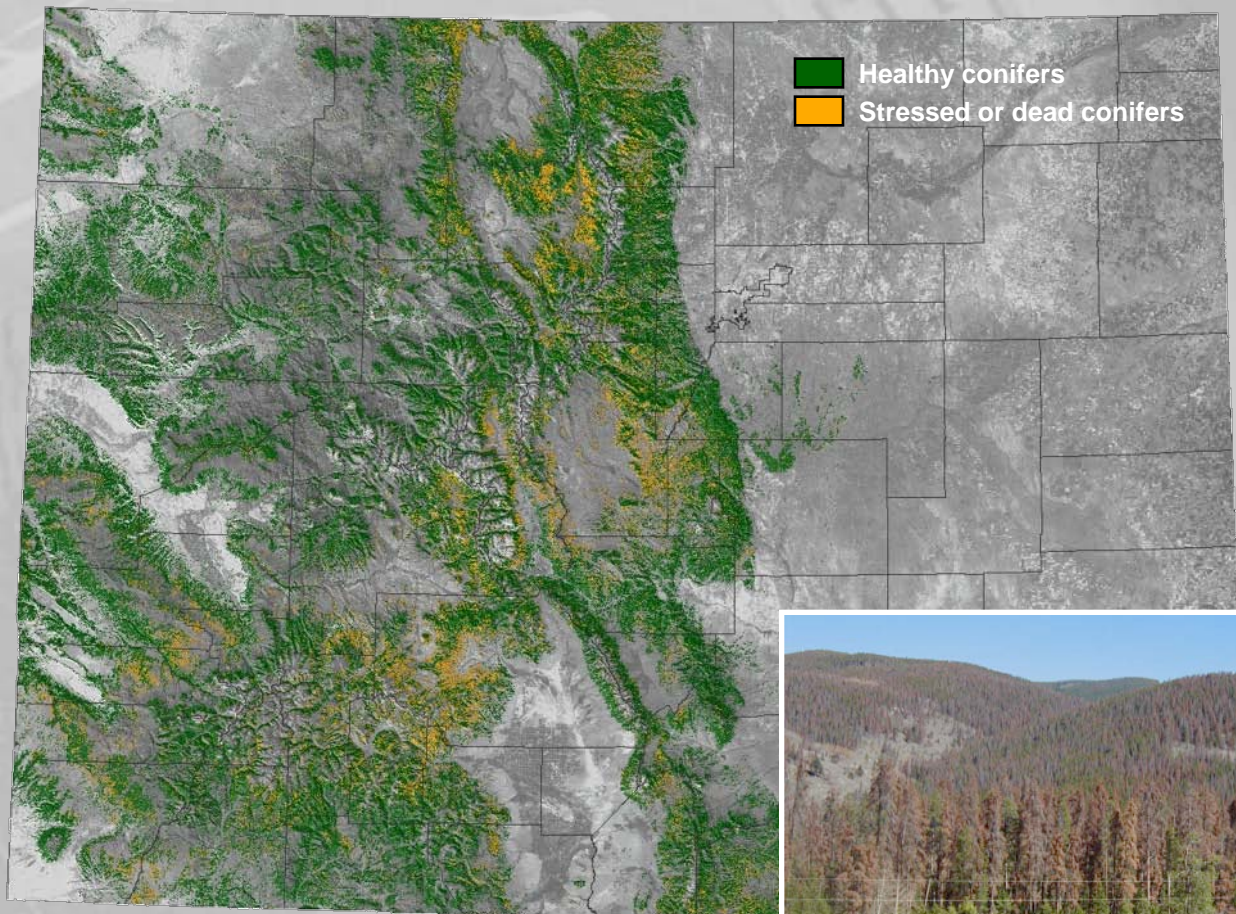
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- **States:**
  - At least 35 use it for forest inventories, wetlands monitoring, invasive species detection, environmental compliance, etc.
  - At least 16 use it to monitor and manage agricultural water use
- **Federal Agencies:**
  - Map damage extent from storms, floods, and wildfires and identifies urban development on or near floodplains
  - Proves and prosecutes for crop-insurance fraud
  - Scan global Landsat imagery to discover changes that require a closer look
  - National Land Cover Database, Monitoring Trends in Burn Severity, LANDFIRE, etc.
- **Public Sector:**
  - Agricultural & educational uses are the most prevalent



# Mapping conifer forest health to promote the use of bio-fuels for power generation

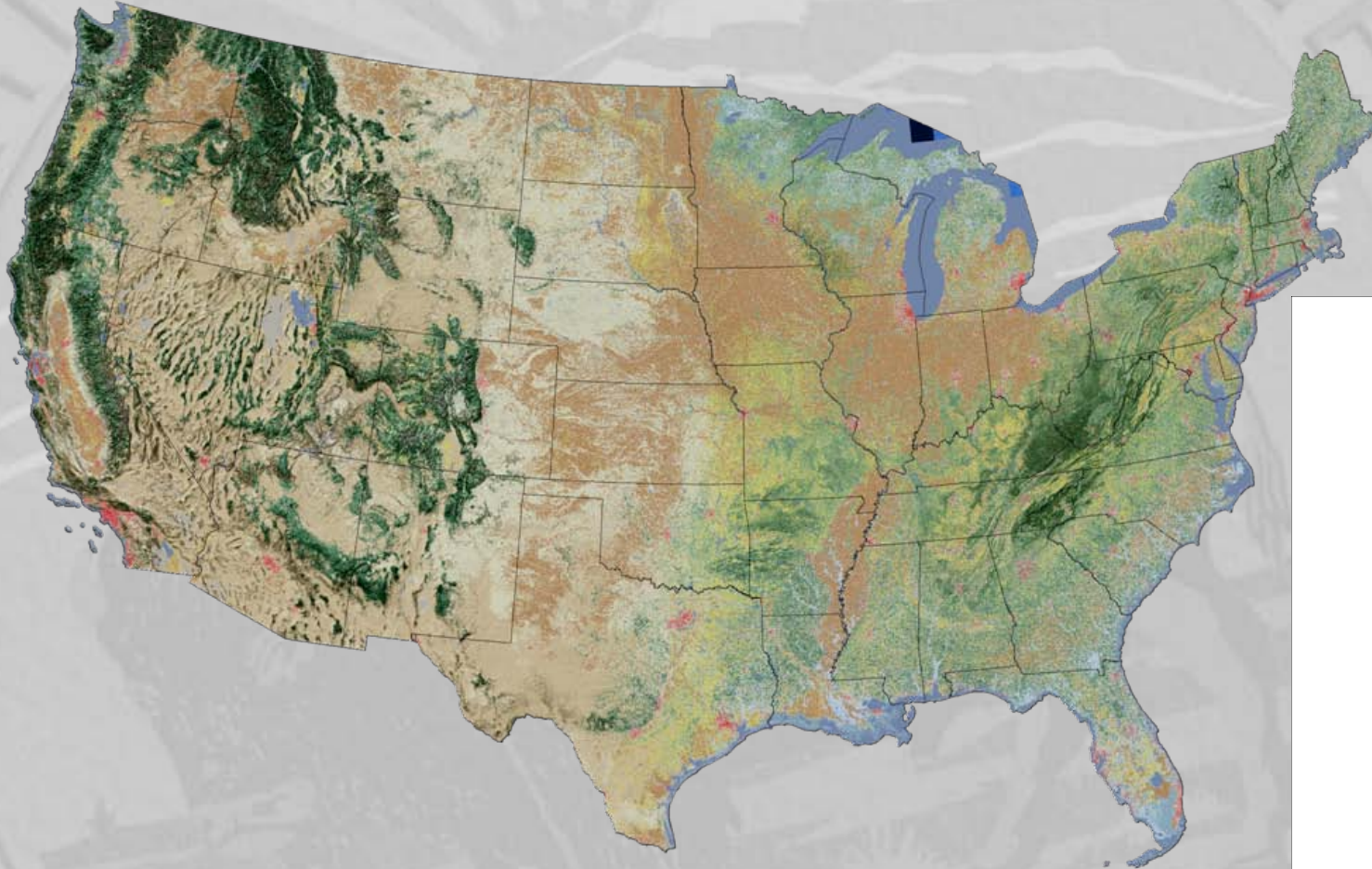
- Landsat derived information of the extent of the pine beetle infestation will aid the economic analysis of wood pellet plants and the associated heating and power generation facilities.
- "There is a 20 year supply of woody biomass from dead or dying trees within a 75 mile radius of the Martin Drake Power Plant." (Terry Meikle, Colorado Springs Utilities biomass project manager, © 2009 Marketwire, Incorporated )
- "The older trees in Colorado's forests are susceptible to pine beetle kill," says Meikle. "By removing the dead trees in a systematic way, we'll help reduce the risk of fire and make the forest healthier."



Colorado

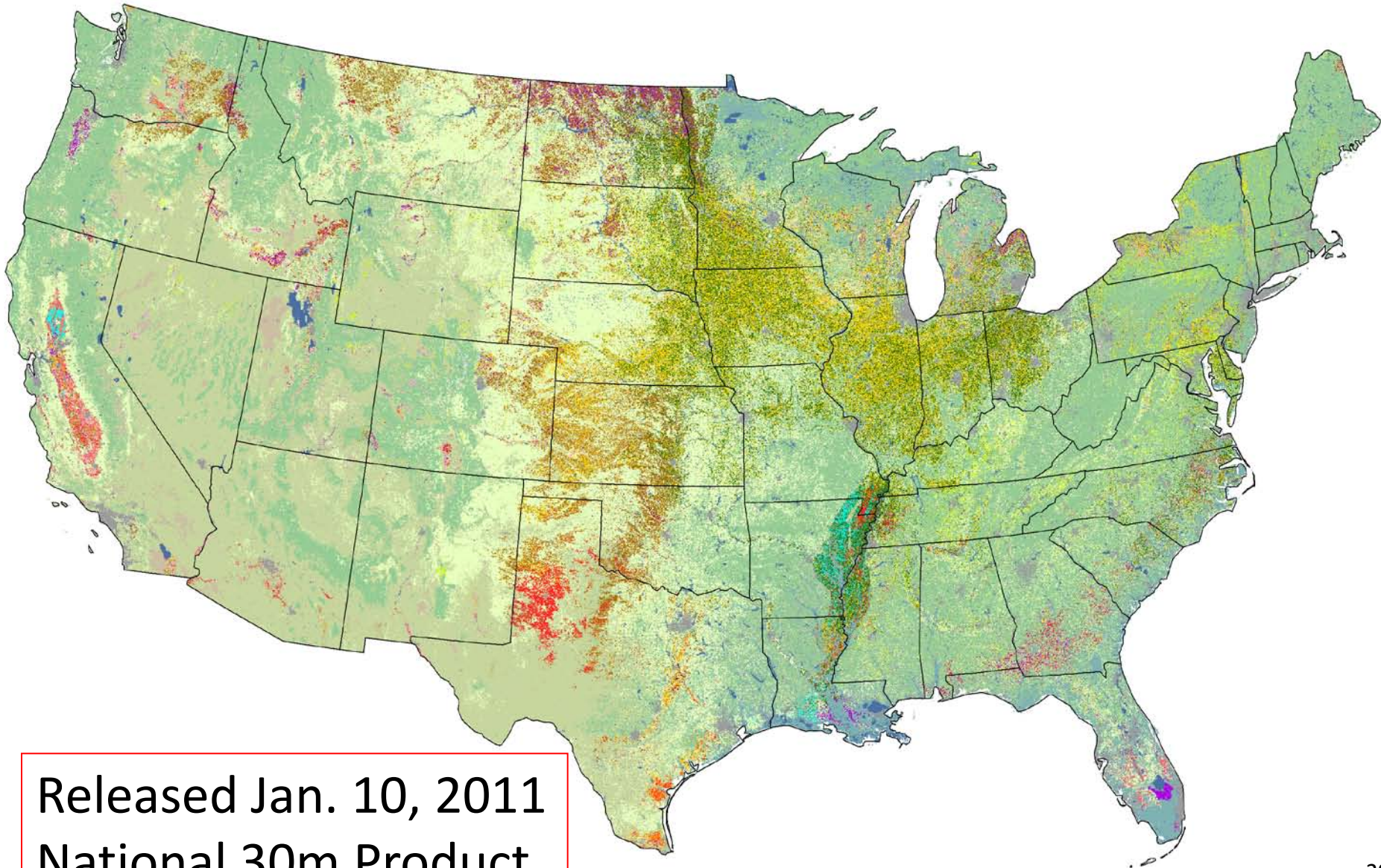


# National Land Cover Database - 2006





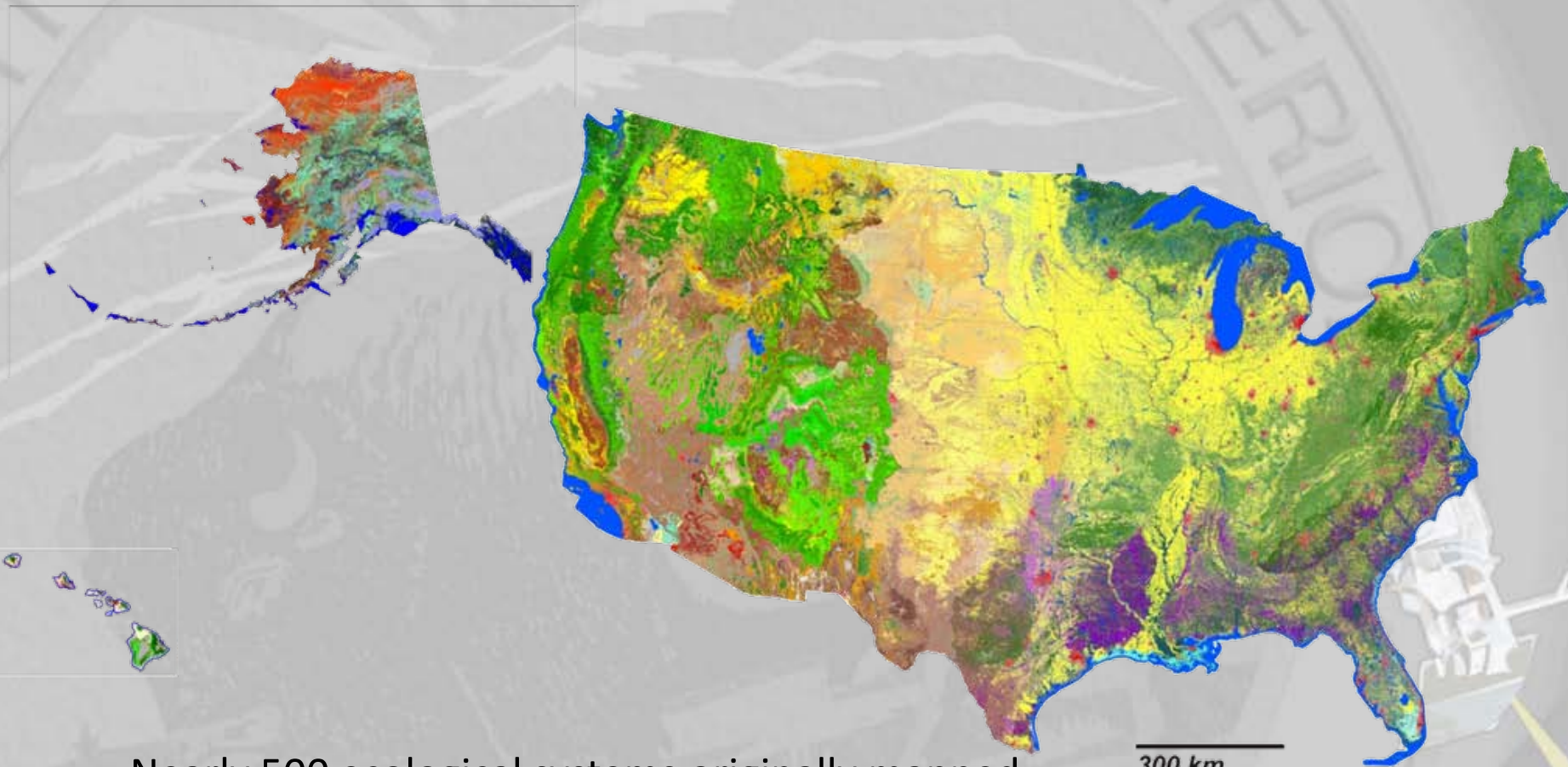
# 2010 Cropland Data Layers



Released Jan. 10, 2011  
National 30m Product



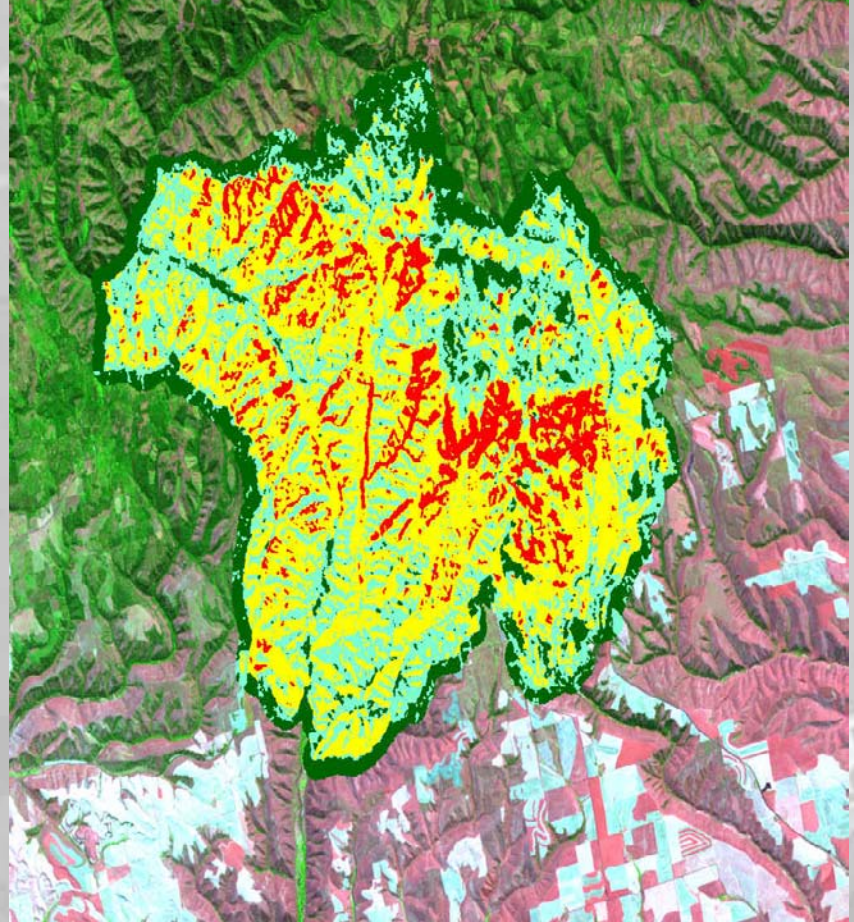
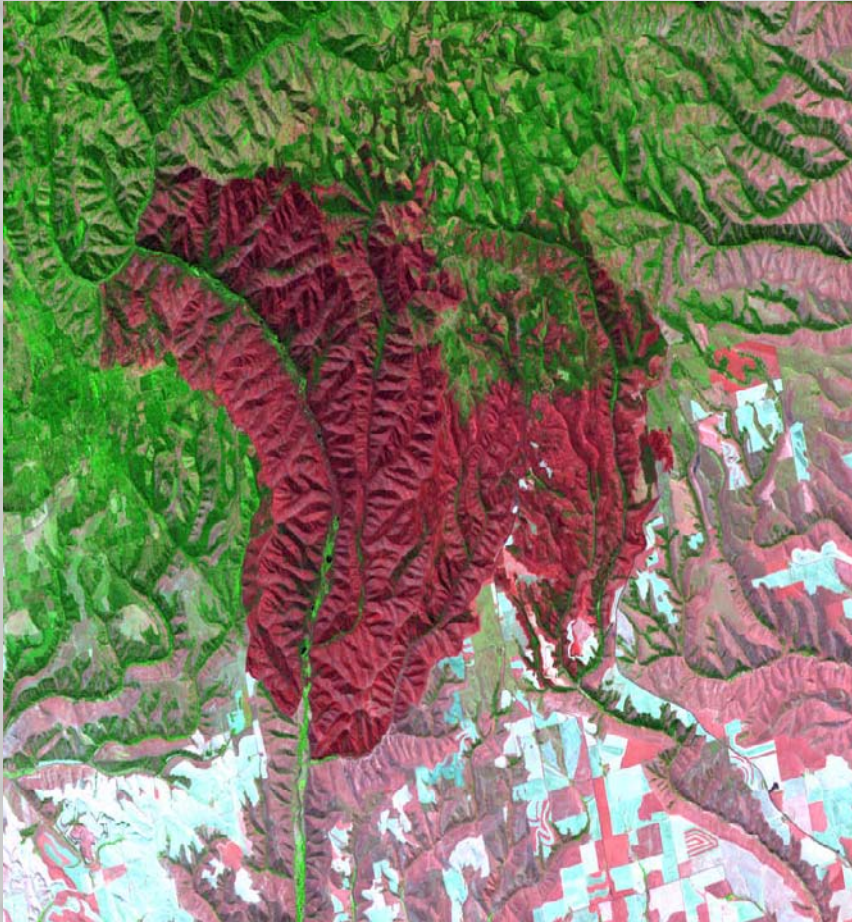
# 2001-era LANDFIRE Existing Vegetation



Nearly 500 ecological systems originally mapped  
National Vegetation Classification System hierarchy



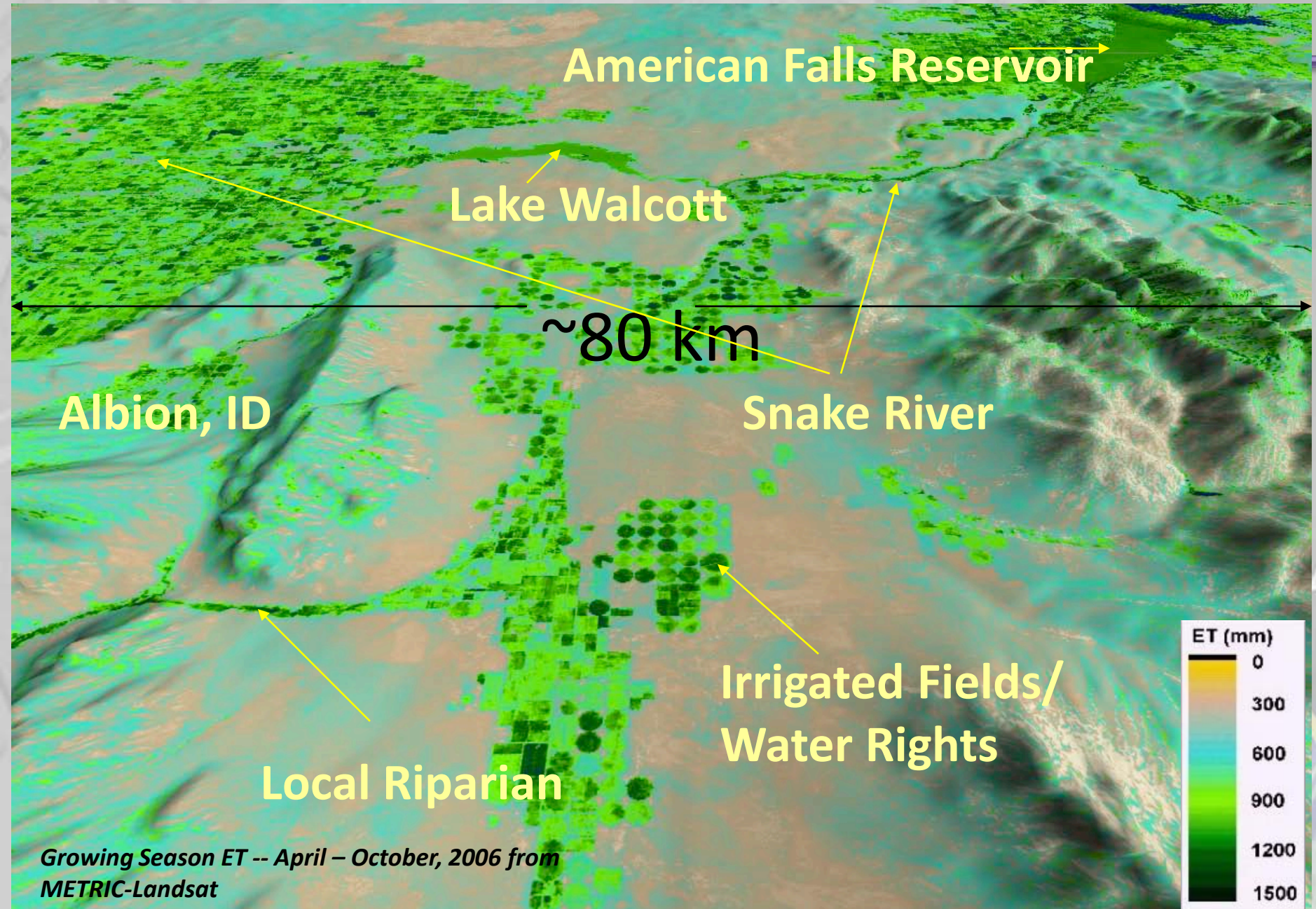
# Landsat - Monitoring Trends in Wildfire Severity



*School Fire – Oregon, 2005*



# Evapotranspiration (ET) at Landsat resolution





# 2009 Award for Harvard's Ash Institute's Innovations in American Government Award

## *Idaho Department of Water Resources and University of Idaho for "Mapping Evapotranspiration from Satellites"*



**"METRIC...is measurably more accurate, fast, and cost-effective than the traditional, cumbersome, slow and expensive methods that were commonly used in the last century."**

**"...it would be practically *impossible* to adjudicate water rights disputes in the future without [TIRS]."**

**"It is measurably effective in that it has distinctive capacities to monitor evapotranspiration and consumptive water use across both space...and time (..with the help of historic Landsat thermal band**



LANDSAT

# ESSENTIAL CLIMATE VARIABLES DERIVED FROM LANDSAT DATA

MODELING  
FORECASTING  
PREDICTION

Snow Cover

Leaf Area Index

Land Cover

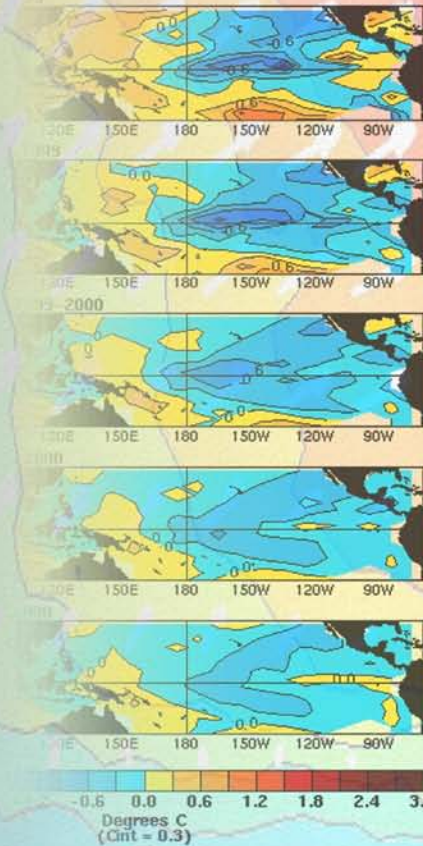
Biomass

Water Extent

Fire Disturbance

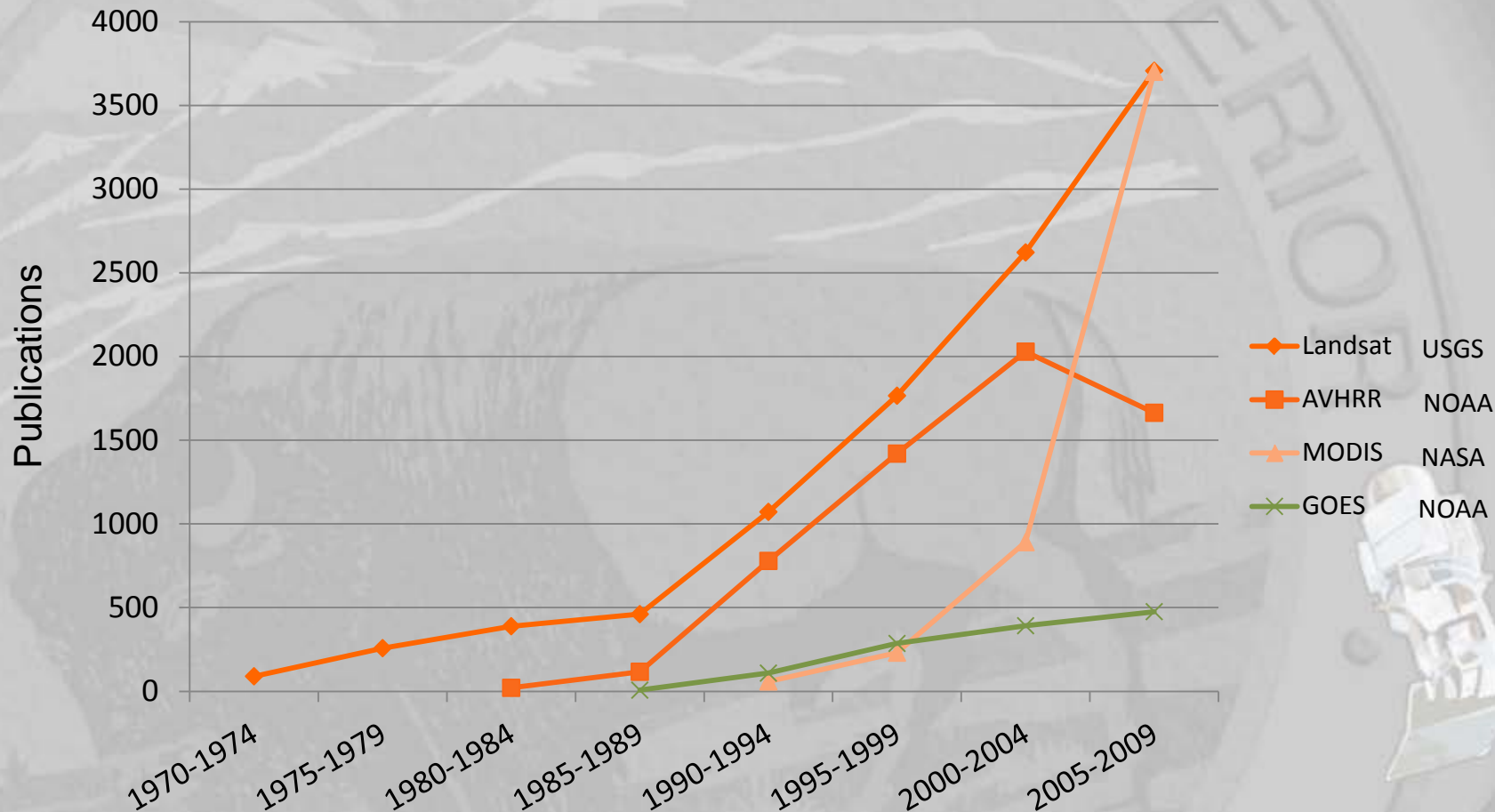
Albedo

Landsat Data





# After 40 Years, Landsat remains the “backbone” of scientific land remote sensing

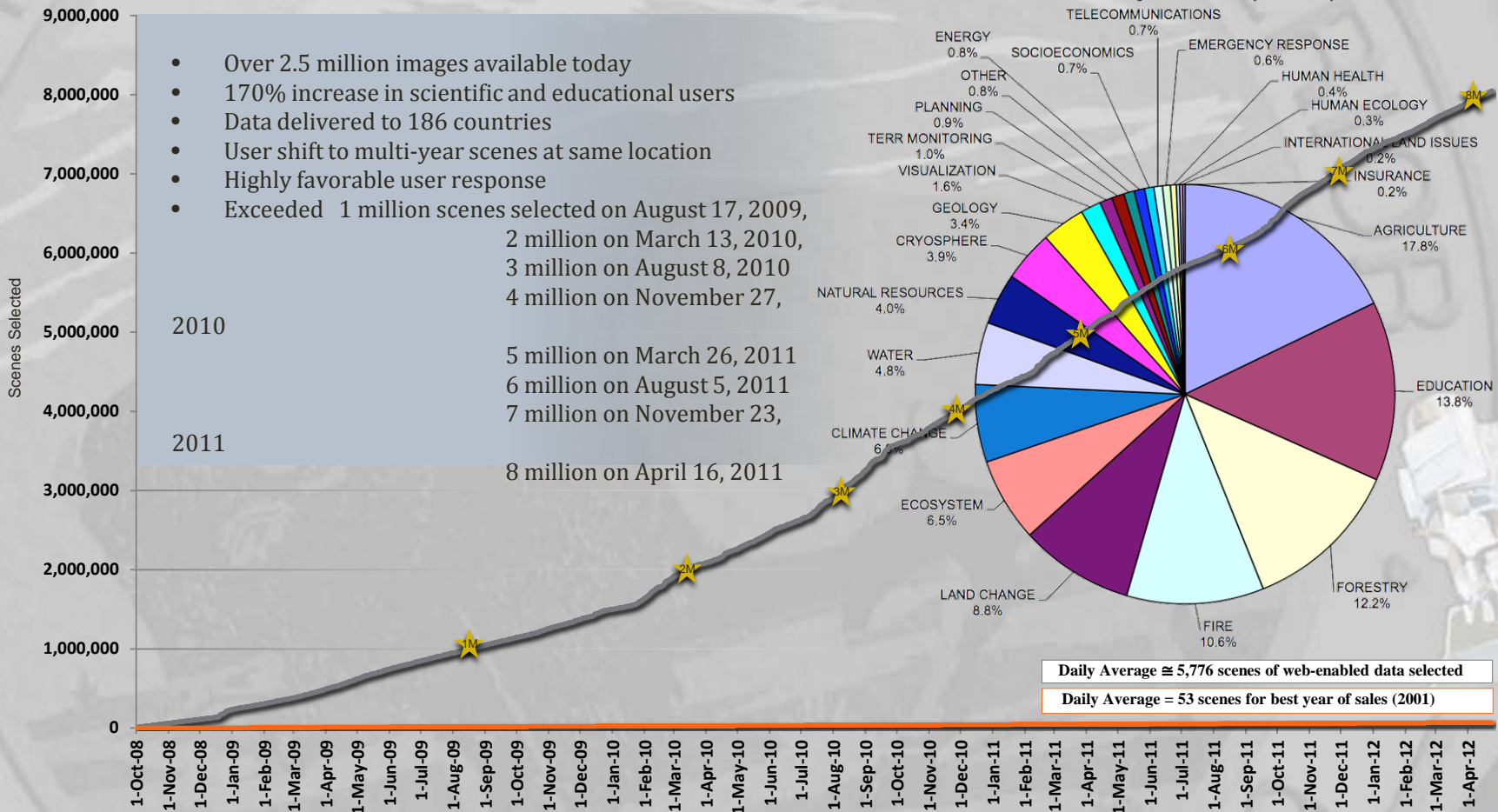


From ISI Web of Knowledge; includes journal and conference articles

# Landsat Use Data & Web-Enabled Distribution

40-year archive of global data provided freely on the Internet

- Over 2.5 million images available today
- 170% increase in scientific and educational users
- Data delivered to 186 countries
- User shift to multi-year scenes at same location
- Highly favorable user response
- Exceeded 1 million scenes selected on August 17, 2009,  
2 million on March 13, 2010,  
3 million on August 8, 2010  
4 million on November 27, 2010  
5 million on March 26, 2011  
6 million on August 5, 2011  
7 million on November 23, 2011  
8 million on April 16, 2011



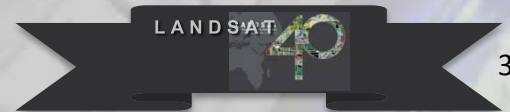
as of April 24, 2012

Total Landsat Scenes Selected By Users Since October 1, 2008



Based on per day delivery

— Actual Web-enabled Scenes Delivered (Cumulative)  
 — Average Scenes Delivered (Based on Best Year of Sales)





# Accessing Landsat Images

USGS Global Visualization Viewer - Windows Internet Explorer

http://glovis.usgs.gov/

File Edit View Favorites Tools Help

USGS science for a changing world Earth Resources Observation and Science Center (EROS)

System Notices (1), 1 Critical

Collection Resolution Map Layers Tools File Help

Downloadable

WRS-2 Path / Row: 29 30 Go

Lat / Long: 43.2 -97.1 Go

Max Cloud: 100%

Scene Information:  
ID: LT50290302011300PAC01  
CC: 0% Date: 2011/10/27  
Qlty: 9 Sensor: TM

Oct 2011 Go

Prev Scene Next Scene

L4-7 Combined Scene List

1000m No Limits Set

USGS

Quick Start Guide User Guide What's New!  
Browser Requirements Download Source Code About Browse Images

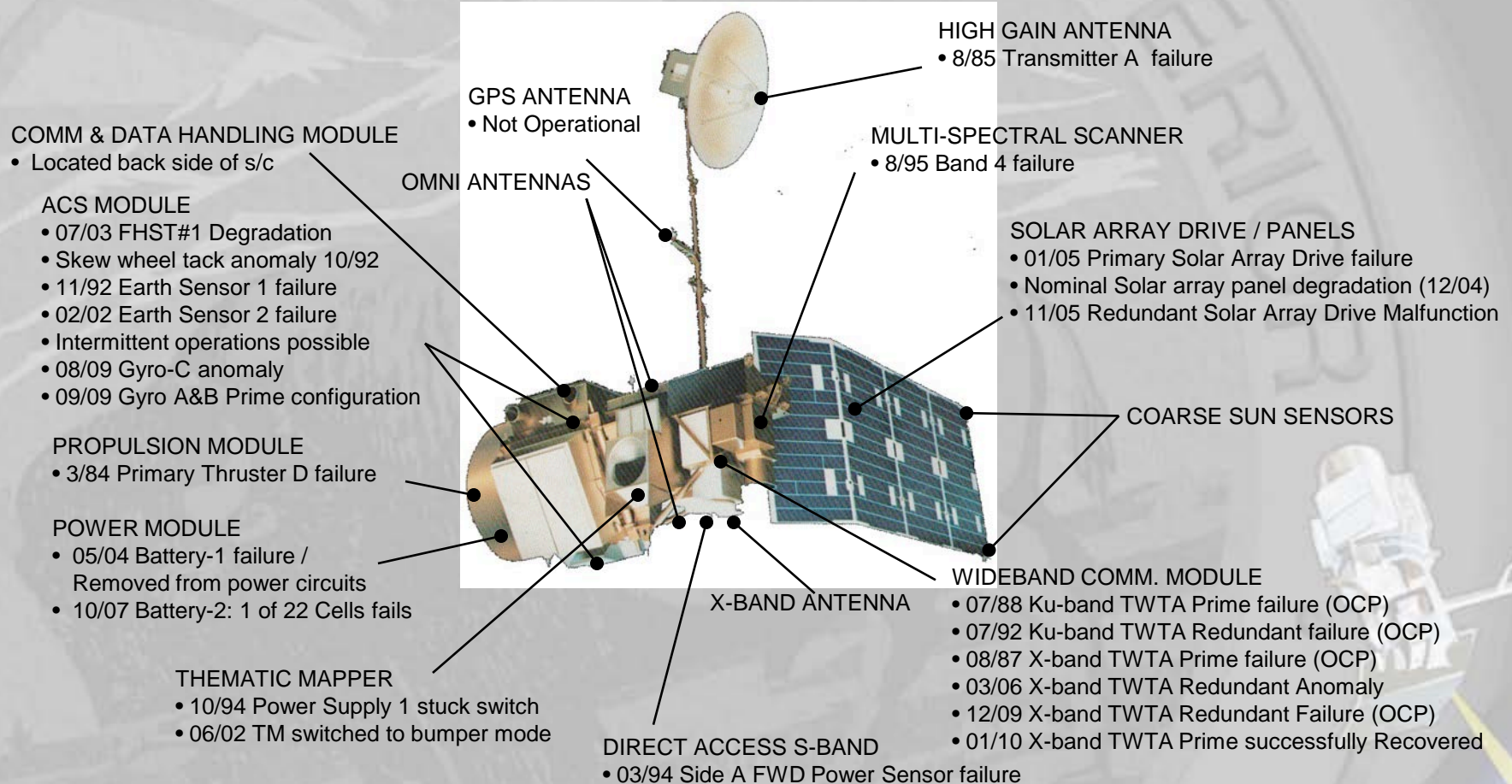
DOI USGS HOME Biology Geography Geology Water

Landsat data available over the Internet at:

<http://glovis.usgs.gov/>

<http://earthexplorer.usgs.gov/>

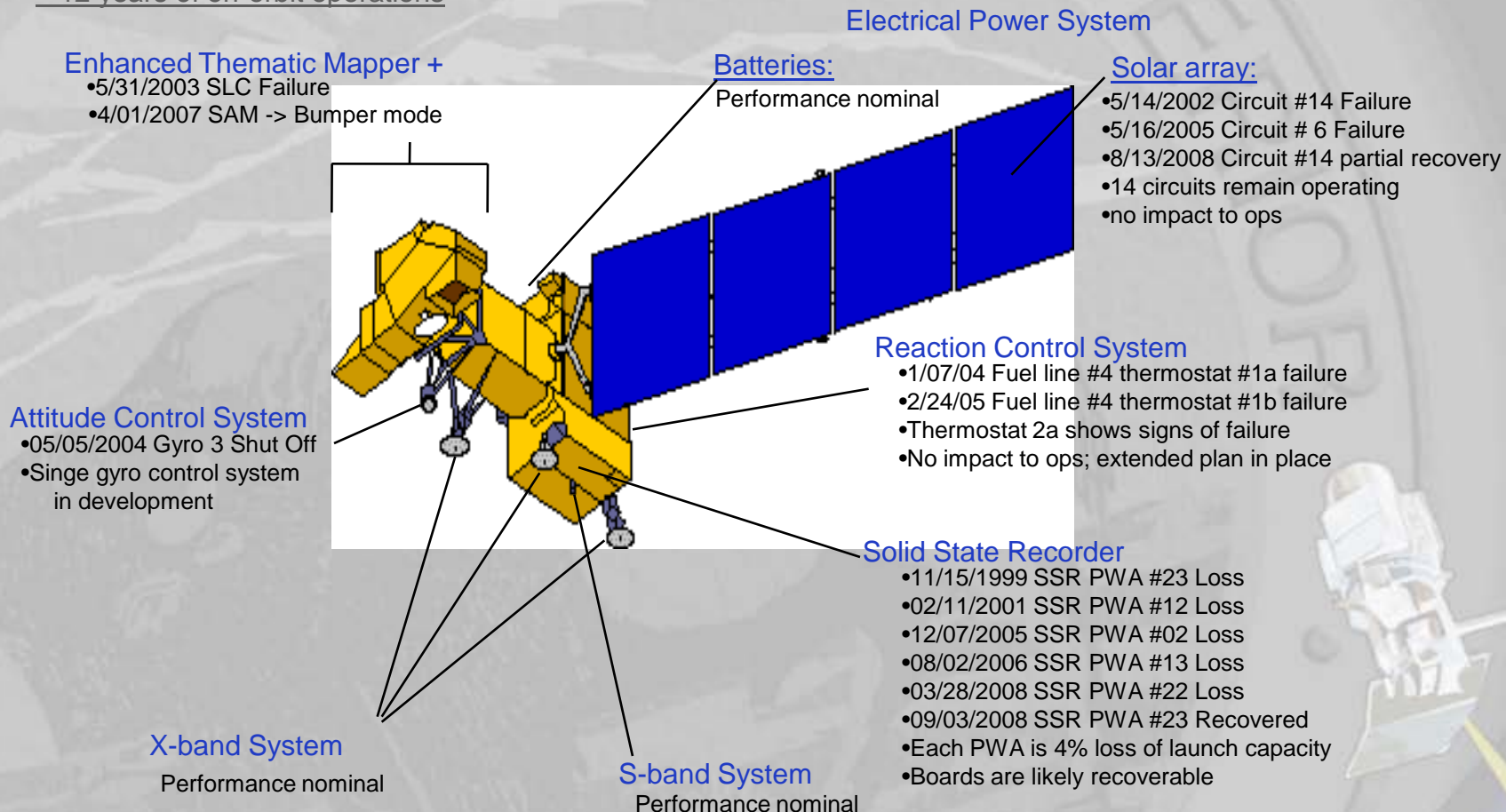
# Landsat 5 Status





# Landsat 7 Status

≈ 12 years of on-orbit operations



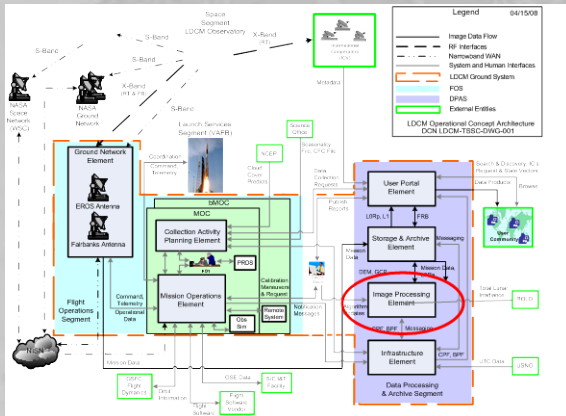
# Landsat Data Continuity Mission (LDCM) or Landsat 8

## Mission Characteristics

- Orbit: Polar, 705km, sun-synchronous (WRS2), 98.2° inclined, mid-morning, 16-day repeat
- **Launch Date: Early 2013; Launch Vehicle: Atlas V**
- Mission Life: 5 Years (with consumables 10 years)
- Mission Project Management: NASA/USGS

## DOI USGS developed Ground System

- 4 design elements

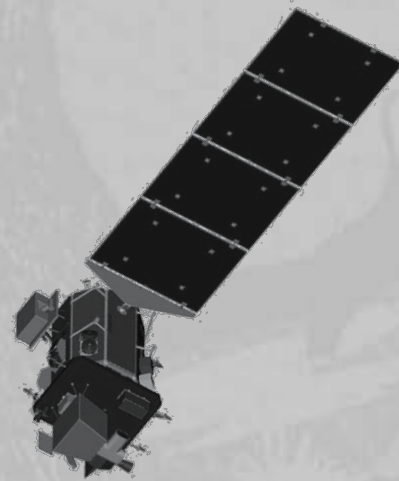


## Operational Land Imager (OLI)

- 9 spectral bands 30m resolution for VIS/NIR/SWIR, 15m for PAN
- 185km swath width
- Collect 400 WRS-2 scenes/day; 265Mbps

## Thermal Infrared Sensor (TIRS)

- TIRS in initial design at NASA; proposed in American Recovery and Investment Act of 2009 Approximately 100m resolution in 2 bands; 185km swath



## Spacecraft

- Observatory mass of 3085kg
- Maximum power of 2130W
- 3Tb Solid State Recorder
- 384Mbps X-band downlink



# Landsat 8



# Landsat 9 and Beyond

- **The USGS Joined NASA in 2000 as its full partner in Landsat Program management**
  - Presidential Decision Directive NSTC-3 (5/94, revised 10/00)
- **Both agencies are funded for Landsat 8 development; funding projected for the USGS operations through 2018**
- **National Space Policy – June 28, 2010**

## ***Land Remote Sensing***

*The Secretary of the Interior, through the Director of the United States Geological Survey (USGS), shall:*

- *Conduct research on natural and human-induced changes to Earth's land, land cover, and inland surface waters, and manage a global land surface data national archive and its distribution;*
- *Determine the operational requirements for collection, processing, archiving, and distribution of land surface data to the United States Government and other users; and*
- *Be responsible, in coordination with the Secretary of Defense, the Secretary of Homeland Security, and the Director of National Intelligence, for providing remote sensing information related to the environment and disasters that is acquired from national security space systems to other civil government agencies.*

*In support of these critical needs, the Secretary of the Interior, through the Director of the USGS, and the NASA Administrator shall work together in maintaining a program for operational land remote sensing observations*

- **USGS is working with NASA and the White House Office of Science and Technology Policy to assess options for Landsat 9 and beyond**



# Questions?



## LANDSAT

Four Decades of Earth Observation  
1972–2012



*"Because Landsat enables us to see Earth's surface so clearly, so broadly, so objectively, we gain invaluable insights about the complexity of Earth systems and the condition of our natural resources."*

— USGS Director Marcia McNutt



Mexico Irrigation  
Landsat 5  
August 3, 2010

# Summary

- Landsat remote sensing satisfies many applications across the government
- Landsat is critical to global change research because of its uninterrupted 40-year global record of landscape change
- Landsats 5 and 7 are well past their design lives; might not last until Landsat 8 is launched
- Landsat 8 is in development and will launch in early 2013
- The Nation needs an operational Landsat Program to ensure Landsat Data Continuity and maintain the Landsat contribution to our environmental, national security and economic interests



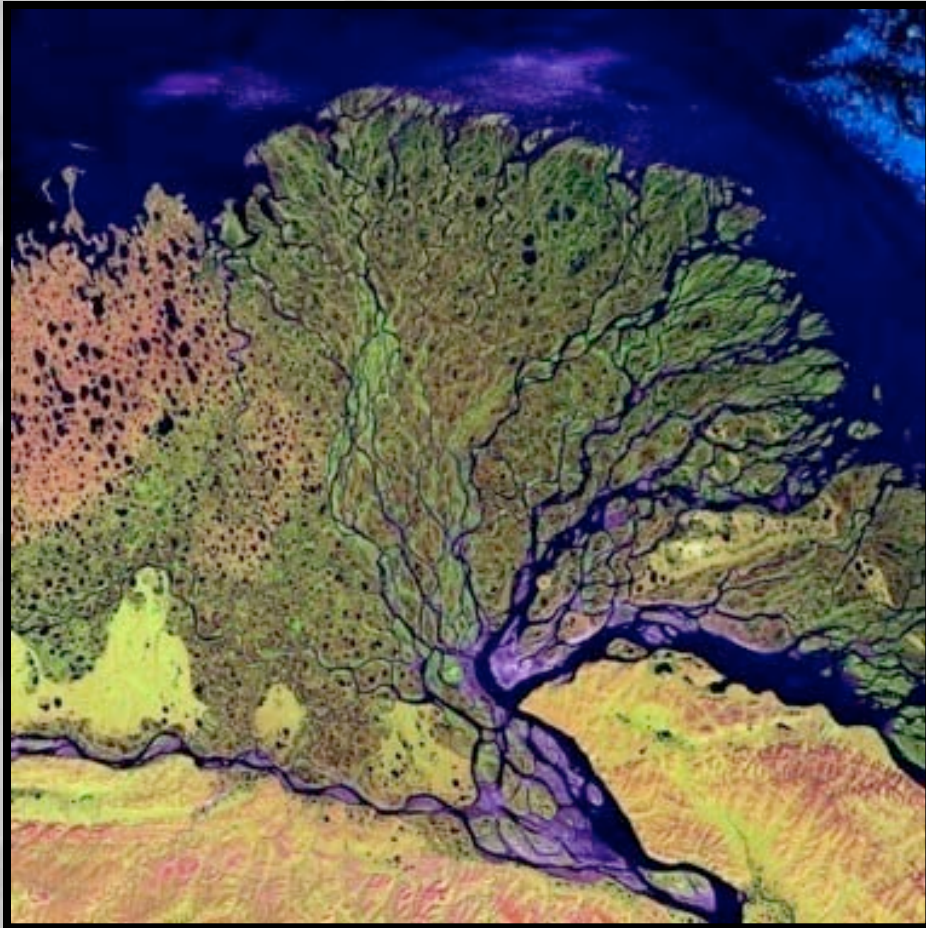
**Landsat 7: Lena Delta**

Image taken 7/27/2000 The Lena River, some 2,800 miles (4,400 km) long, is one of the largest rivers in the world. The Lena Delta Reserve is the most extensive protected wilderness area in Russia. It is an important refuge and breeding grounds for many species of Siberian wildlife.

*Landsat is a unique National Asset*



# Thank You!



“Man must rise above the Earth -- to the top of the atmosphere and beyond -- for only thus will he fully understand the world in which he lives.” – Socrates 500 B.C.

(469-399 BC)

You can see a lot by just looking –  
Yogi Berra

#### Landsat 7: Lena Delta

Image taken 7/27/2000 The Lena River, some 2,800 miles (4,400 km) long, is one of the largest rivers in the world. The Lena Delta Reserve is the most extensive protected wilderness area in Russia. It is an important refuge and breeding grounds for many species of Siberian wildlife.