Developing Climate Data Records and Essential Climate Variables from Landsat Data

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NOAA National Climate Data Center

U.S. Department of the Interior
U.S. Geological Survey

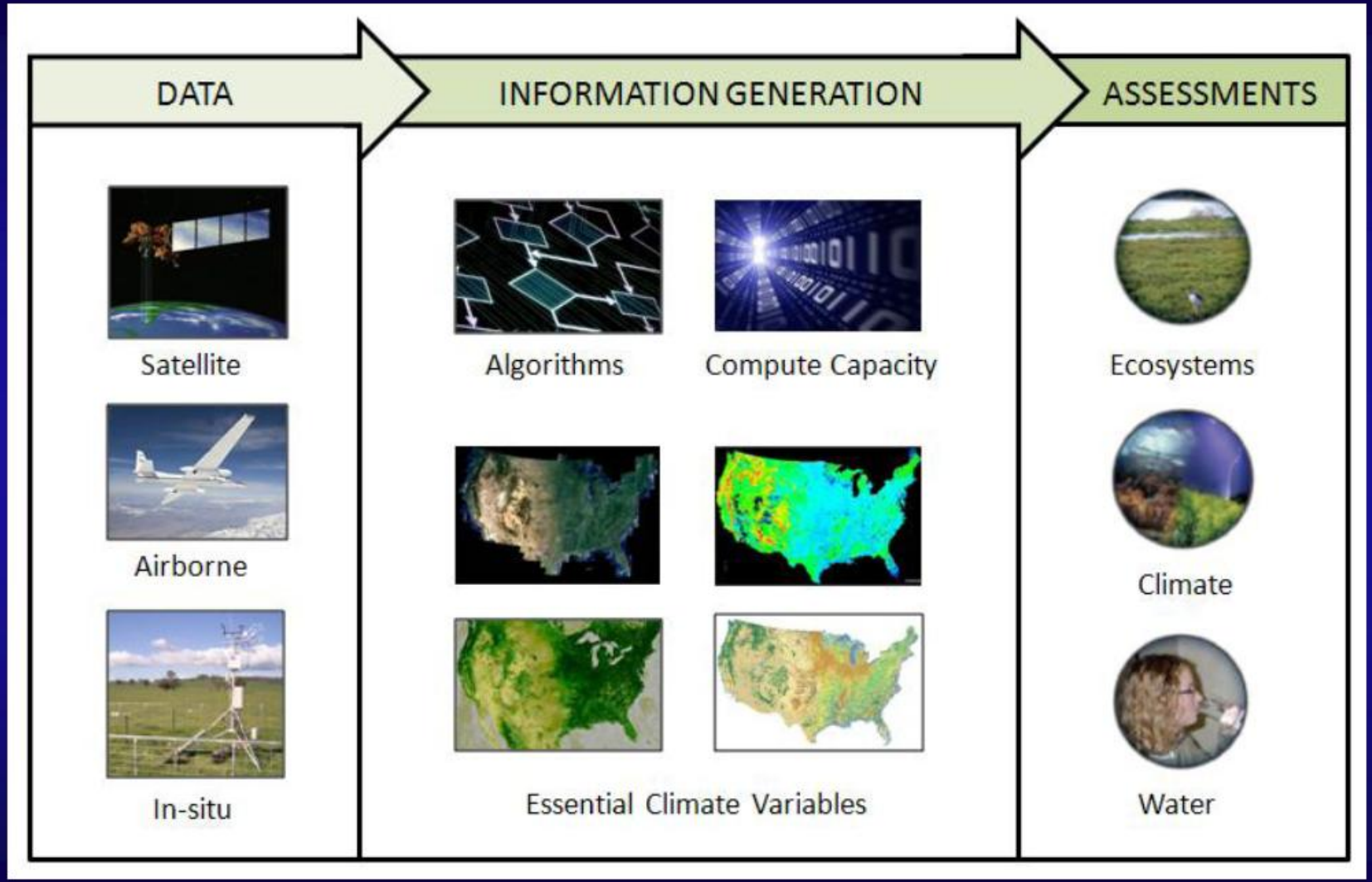
Outline

- Objectives
- Science Drivers
- Collaboration
- Example Products and Applications
- Summary

Objectives

- Provide continuity of observations and measurements to support modeling and decision-making
- Construct long term data records to establish historical trends and enable future projections
- Remove the burden of processing from the end user – readily usable information
- Enable quantitative assessments of land surface change – terrestrial monitoring

Conceptual Framework



Science Drivers

- U.S. Global Change Research Program
  - Long term, high quality observations are essential for defining the current state of the Earth's system, discovering the magnitude and sources of past trends, and providing the scientific basis for future predictions and variability
- U.S. Climate Change Science Program
  - Understanding the interaction between land use and climate variability and change requires the systematic collection and integration of remotely sensed and ground-based observations
- National Research Council
  - Identified land use dynamics as one of the grand challenges for environmental research
- North American Carbon Program
  - Rates of change in land cover, forest disturbance and recovery
- Global Climate Observing System (GCOS)
  - Essential climate variables (ECVs) to support UNFCCC and IPCC assessments

Consistent Terrestrial Measurements

- The value of the Landsat archive for understanding global change is clearly expressed in the USGCRP strategic science plan:
  - ***"One of the great challenges is how to relate human incentives, behavior and action at particular localities to land cover change at broader (e.g., regional) geographic regions. The fine spatial resolution of Landsat images along with its global geographic extent provides the necessary data for making this linkage." (Climate Change Science Program, 2003)***
- No cost access to the Landsat archive has enabled unprecedented opportunities for research and operational applications

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USGS Land Remote Sensing ECV Goal

- Develop science-quality, applications-ready, time-series of key terrestrial variables will be produced using historical and current Landsat data on an operational basis.

- The terrestrial variables will follow the guidelines established through the Global Climate Observing System (GCOS).

Why Use Landsat Data?

- Data are of a spatial resolution at which natural and human-induced land change can be differentiated
- The archive covers more than 38+ years, with the best calibrated record dating to 1982
- The data provide a unique framework within which to achieve scaling among multiple resolutions (field, aircraft, satellite)
- Global coverage enables studies at continental scales

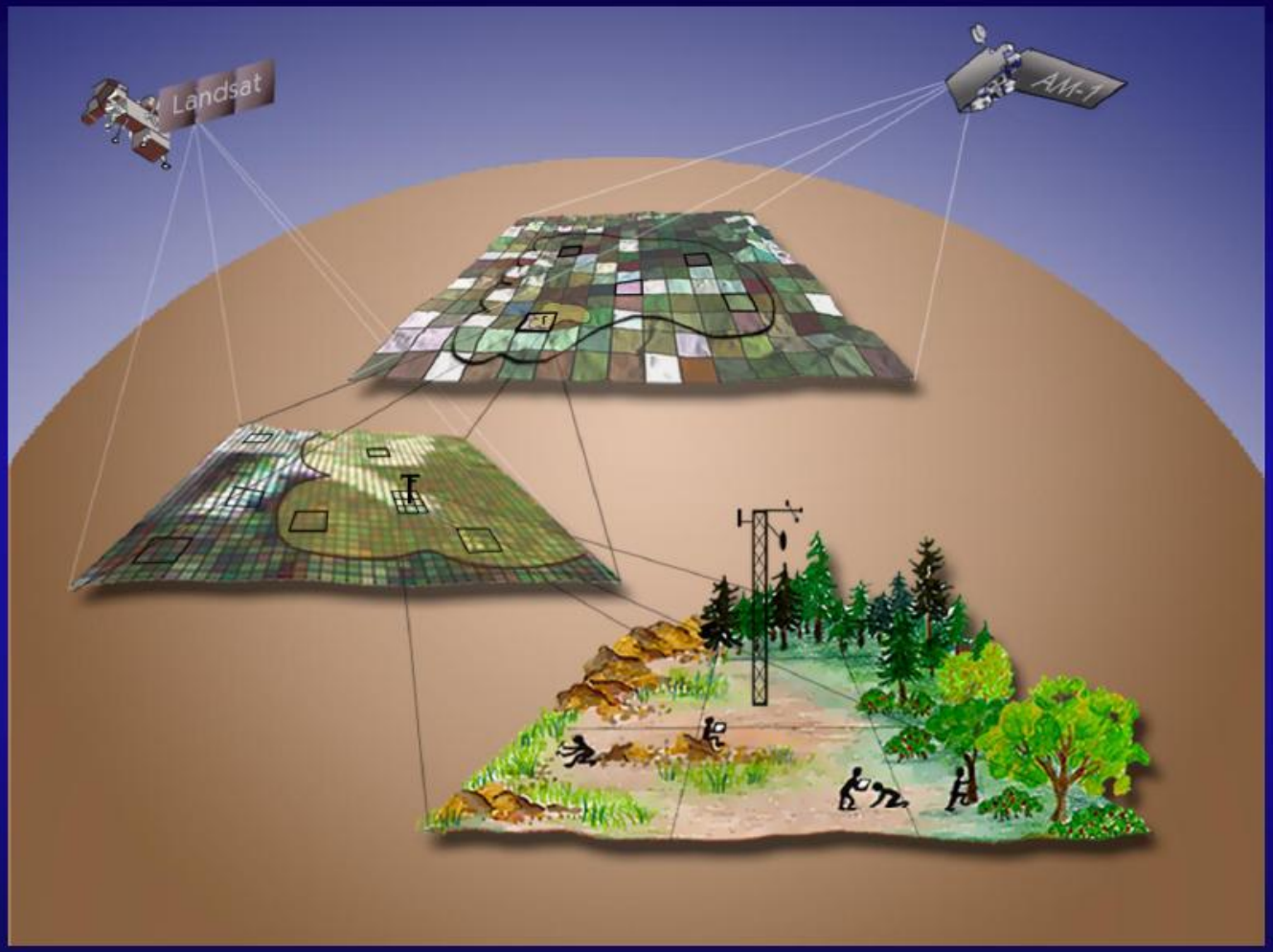
Framework for Scaling Multiple Observations

MODIS – AVHRR

Landsat

Aircraft

Ground



Courtesy of Warren Cohen / Bigfoot Project, Oregon State University

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Definitions

- **Fundamental climate data record (FCDR)**
  - Long term satellite data record, involving a series of instruments, with potentially changing approaches, but with overlap and calibrations sufficient to allow the generation of homogeneous products providing a measure of the independent variable that is accurate and stable enough for climate monitoring.

- **Thematic climate data record (TCDR)**
  - Geophysical variables derived from the FCDRs, with well-defined levels of uncertainty. An ongoing program of correlative in situ measurements is required for validation.

- **Essential climate variable (ECV)**
  - Measurements that are technically and economically feasible for systematic observation. Variables that are currently feasible for global implementation for the Global Climate Observing System (GCOS), and have high impact on the UNFCCC and IPCC requirements.

Global Climate Observing System

Domain	Subdomain	Essential Climate Variable
Atmospheric (over land, sea and ice)	Surface	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed/direction, Water vapour
	Upper Air	Earth radiation budget, Upper-air temperature, Wind speed and direction, Water vapour, Cloud properties.
	Composition	Carbon dioxide, Methane, Ozone, Other long-lived long lived greenhouse gases, Aerosol properties
Oceanic	Surface	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean color, Carbon dioxide partial pressure.
	Subsurface	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.
Terrestrial	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance.	

[1]Soil moisture is not listed as an ECV, but has been recognized by the GCOS Implementation Plan as an emerging ECV.

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Candidate Landsat ECVs

Terrestrial ECV	Technical Consideration			Requirements / Demand		
	Landsat Potential	USGS Readiness	USGS Uniqueness	USGS Relevance	Importance to DOI	Overall Community Demand
*Land Cover	High	High	High	High	High	High
*Leaf Area Index	High	Low	Low	Medium	Medium	Medium
FPAR	High	Low	Low	Medium	Low	Low
Biomass	Low	Low	Low	High	High	High
*Albedo	Medium	Low	Low	Medium	Low	Low
*Fire Disturbance	Medium	High	Medium	High	High	High
*Surface Water	High	High	Medium	High	High	Medium
*Snow / Ice	Medium	Medium	Low	Medium	Medium	Medium
Soil Moisture	Low	Medium	Low	Medium	Medium	Medium

*ECVs with highest initial potential for development

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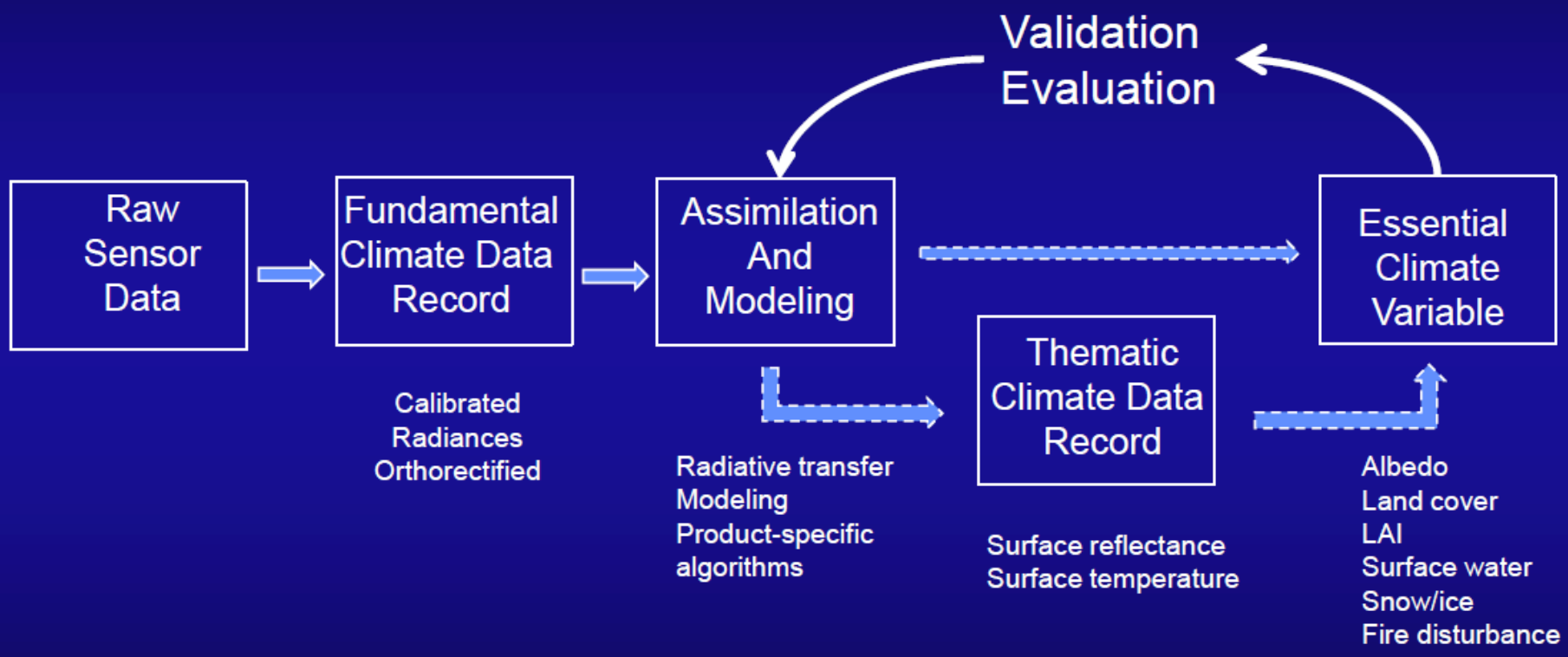
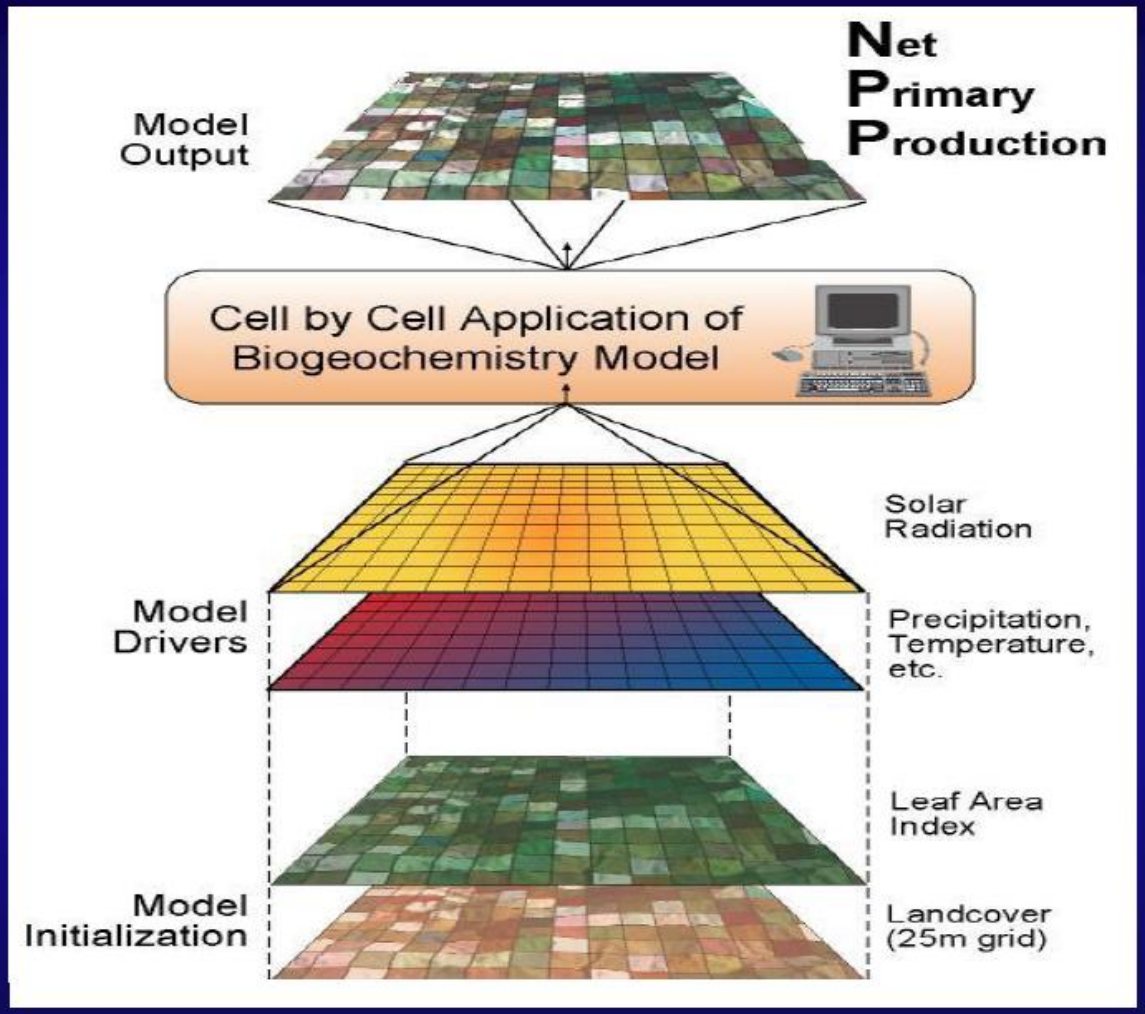
Processing Data into Information



CDRs and ECVs are required for Modeling



Courtesy Rama Nemani, NASA Ames Research Center

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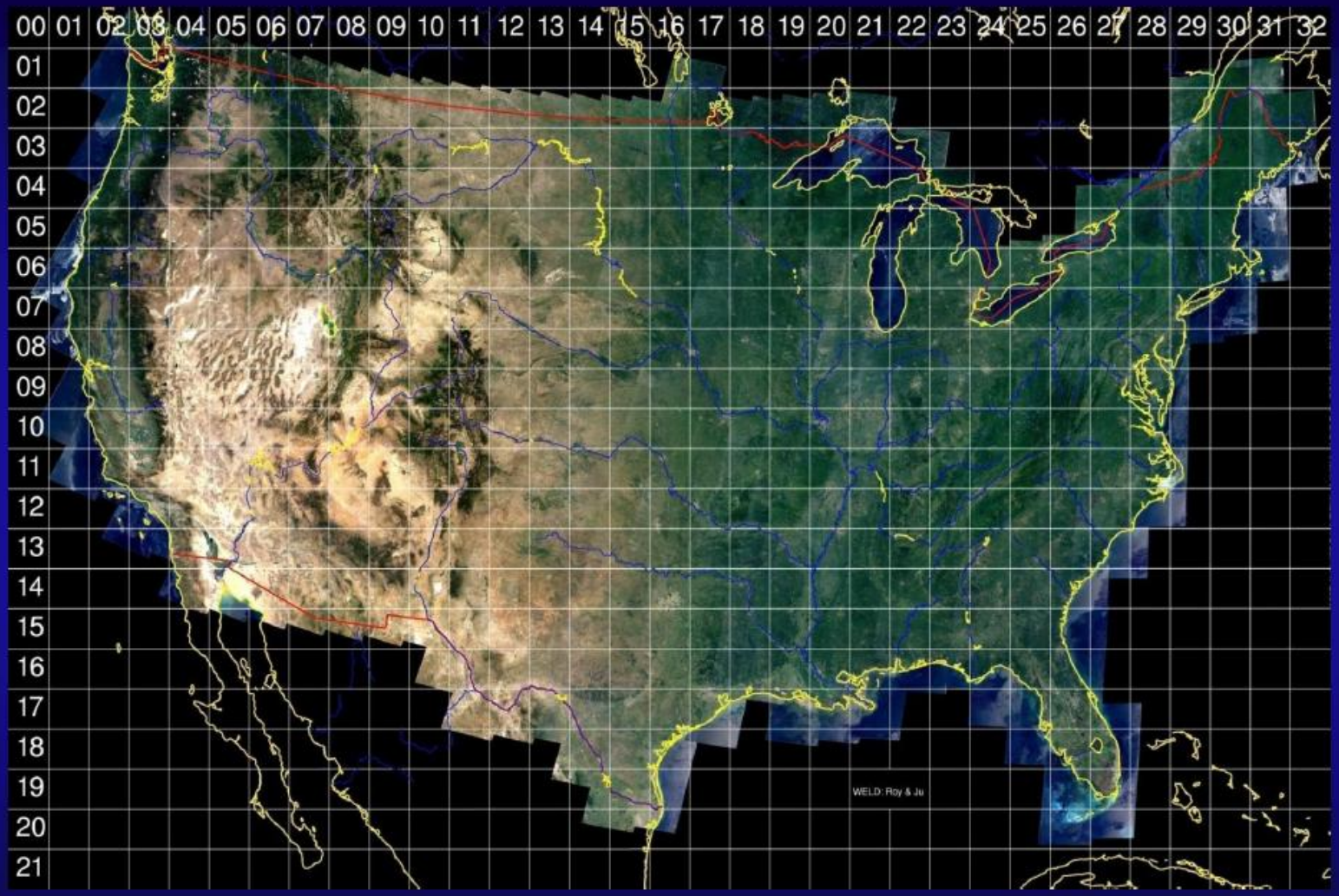
Collaborators in Developing Capabilities

- Web Enabling of Landsat Data (WELD) – David Roy, South Dakota State University
- Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) – Jeff Masek, Feng Gao (NASA GSFC), and Eric Vermote (UMD)
- Deriving Biophysical Products (LAI, fAPAR) from Landsat Data – Rama Nemani, NASA Ames Research Center
- Land Surface Temperature – John Schott (RIT) and Simon Hook (JPL)
- USGS Science Centers – product validation and evaluation, applications development

Importance of Collaborations

- Build upon existing bodies of knowledge
- Leverage expertise within the research community
- Transition demonstrated successes from research & development into operations
- Product evaluation and validation

Calibration and Consistent Gridding



Courtesy of David Roy, SDSU – WELD Project

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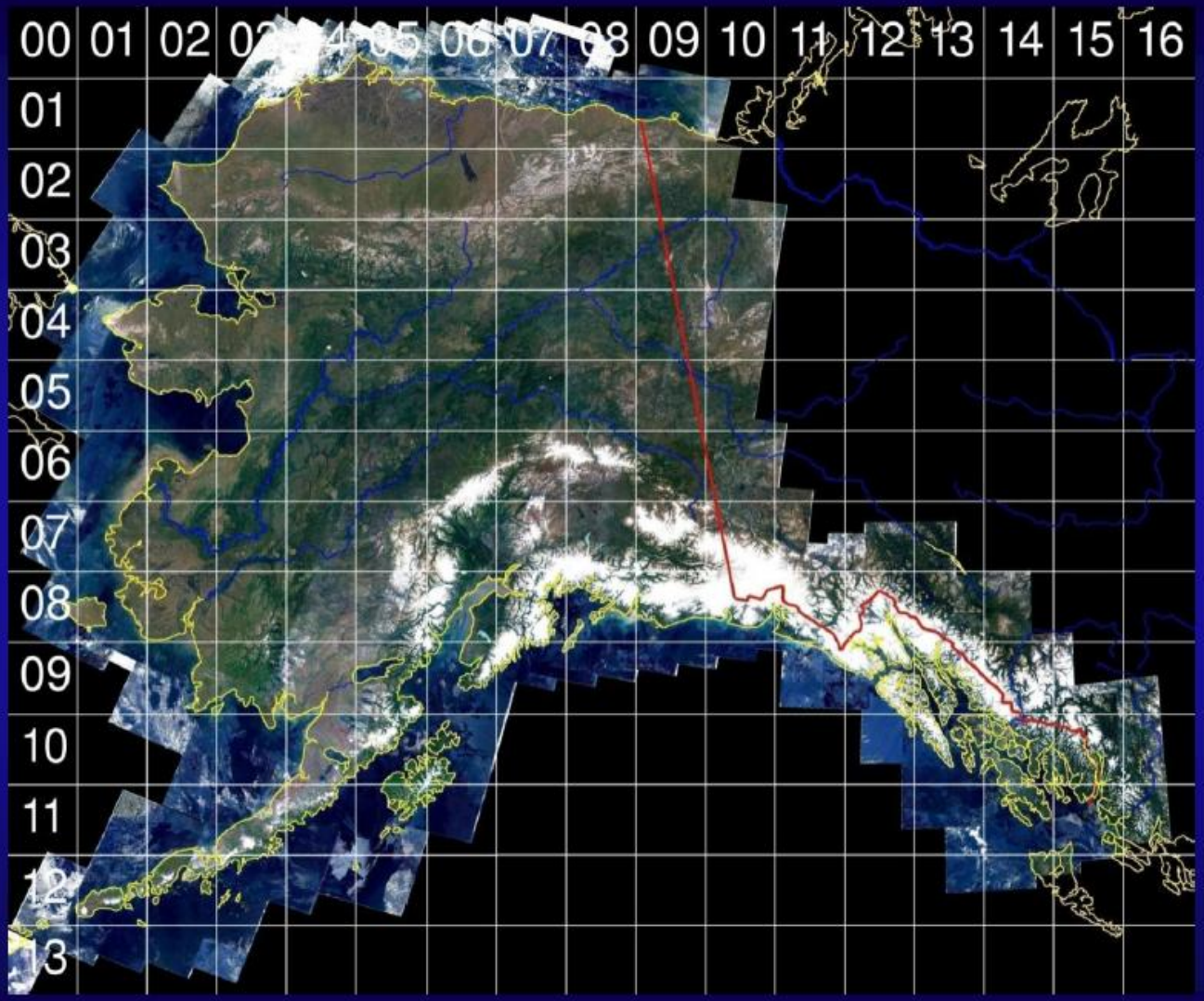
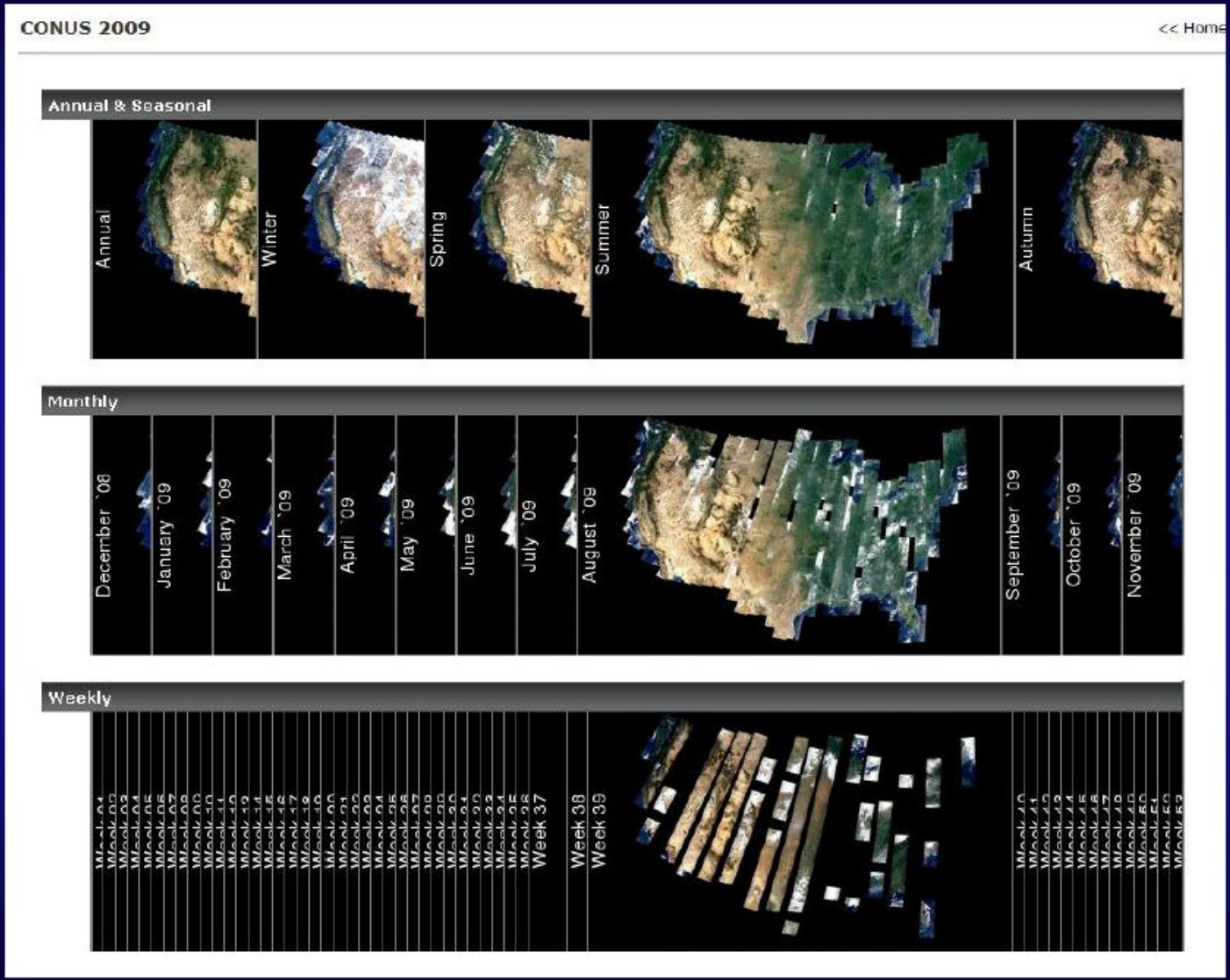
Near Real-time Compositing



Courtesy of David Roy, SDSU – WELD Project

Never Before Provided Clear Views



Mosaic of Adjacent TM Scenes (DNs)

43/34
JUL 22 07

42/34
JUL 28 06

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Surface Reflectance Mosaic

43/34
JUL 22 07

42/34
JUL 28 06

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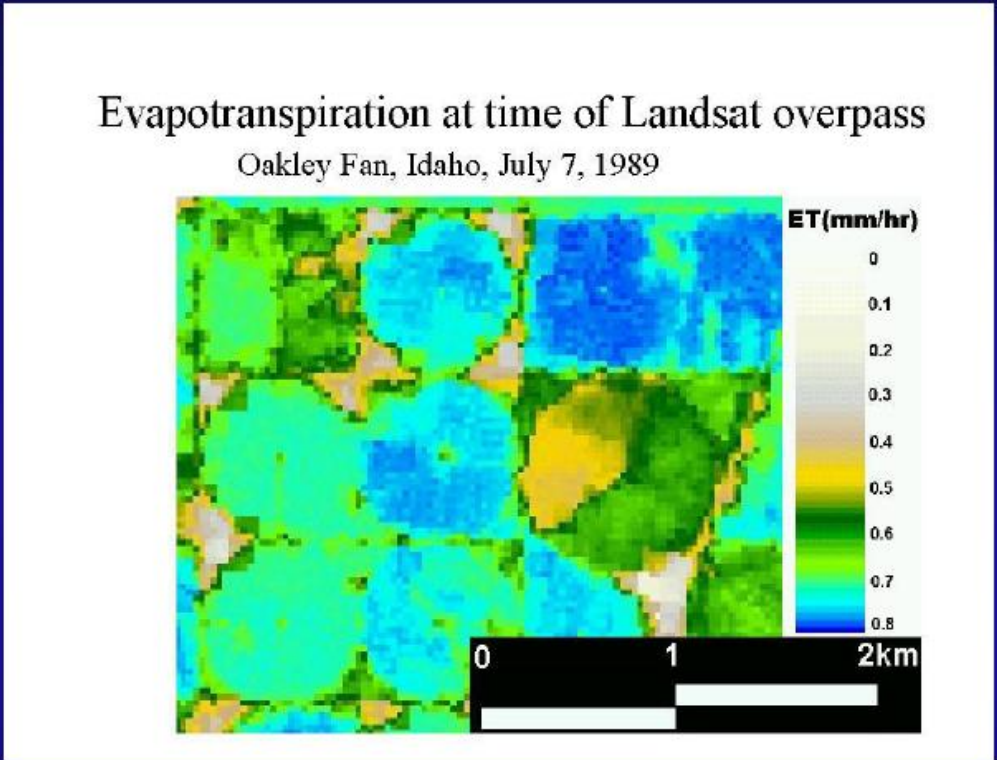
Importance of Landsat Thermal Data

- Landsat thermal data are used operationally to monitor water consumption on a field-by-field basis
- 13 states and 26 countries use Landsat thermal data operationally



Courtesy of Rick Allen / University of Idaho

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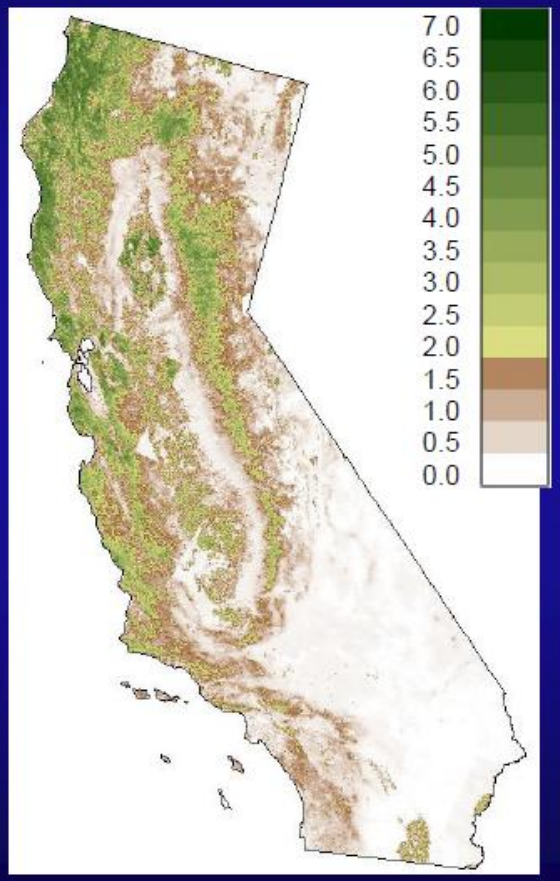
Leaf Area Index - California

L1T At-sensor Radiance (FCDR)

Surface Reflectance (TCDR)

Leaf Area Index (ECV)



Courtesy Rama Nemani, NASA Ames Research Center

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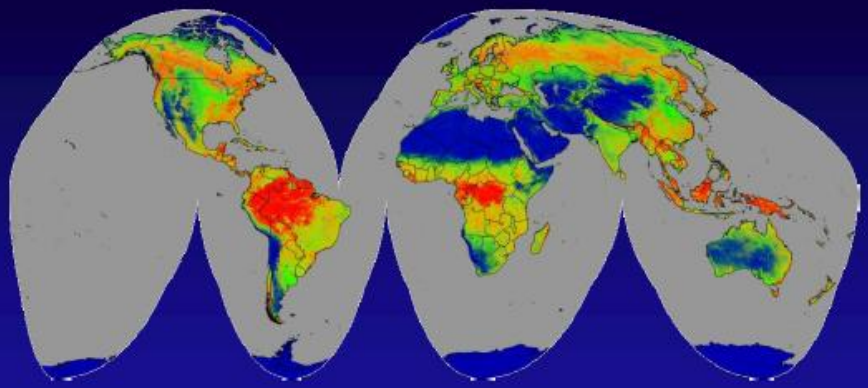
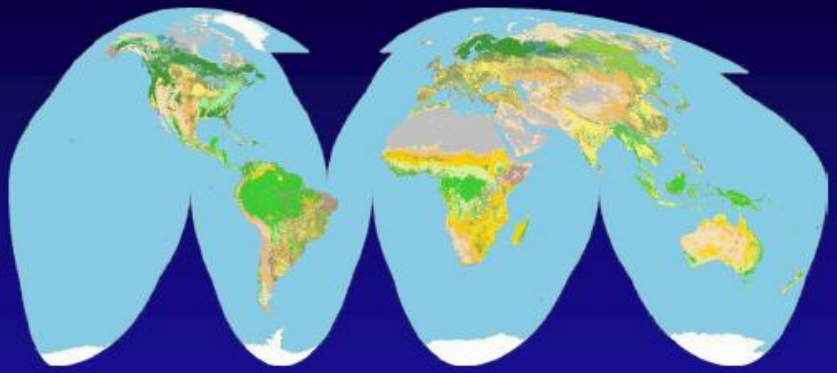
GEO Global 30m Land Cover ECV





Annual land cover continuous variables

- Quantitative annual continuous measures of per pixel percent tree, shrub, herbaceous, water, snow/ice, and barren cover.
- Change products

Mid-decadal year land cover types

- Land cover categories (TBD) consistent with FAO Land Cover Classification System (LCCS)
- Maps and statistical estimates of major land cover types
- Complementary with other global land cover products (e.g., MODIS land cover, Globecover)

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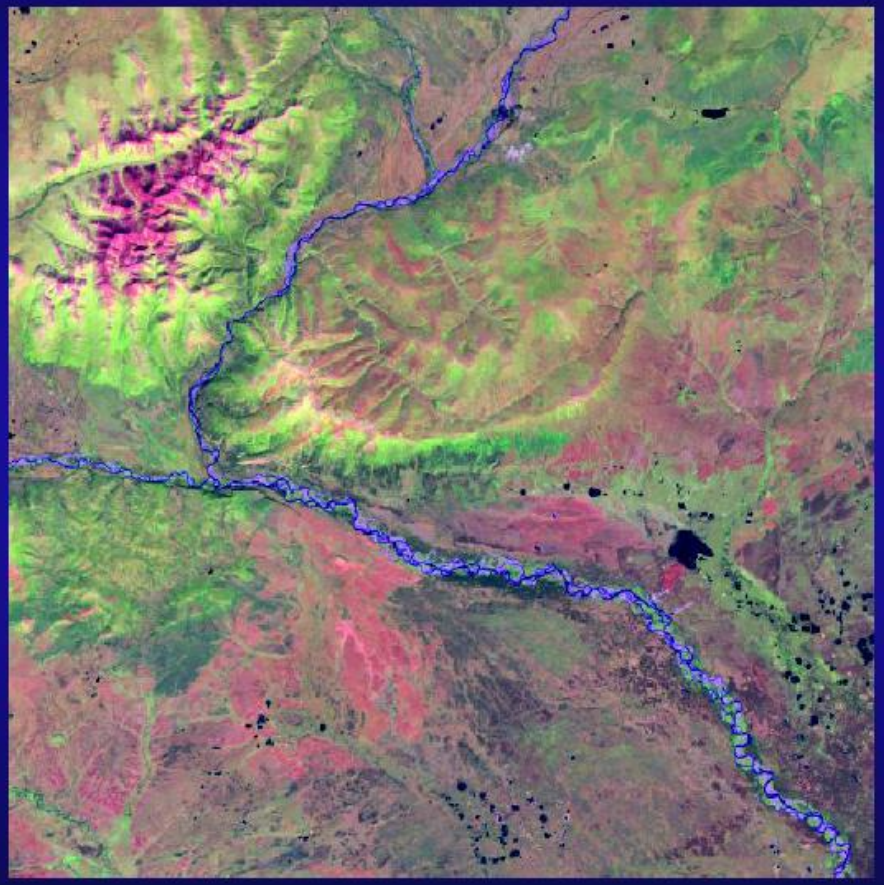
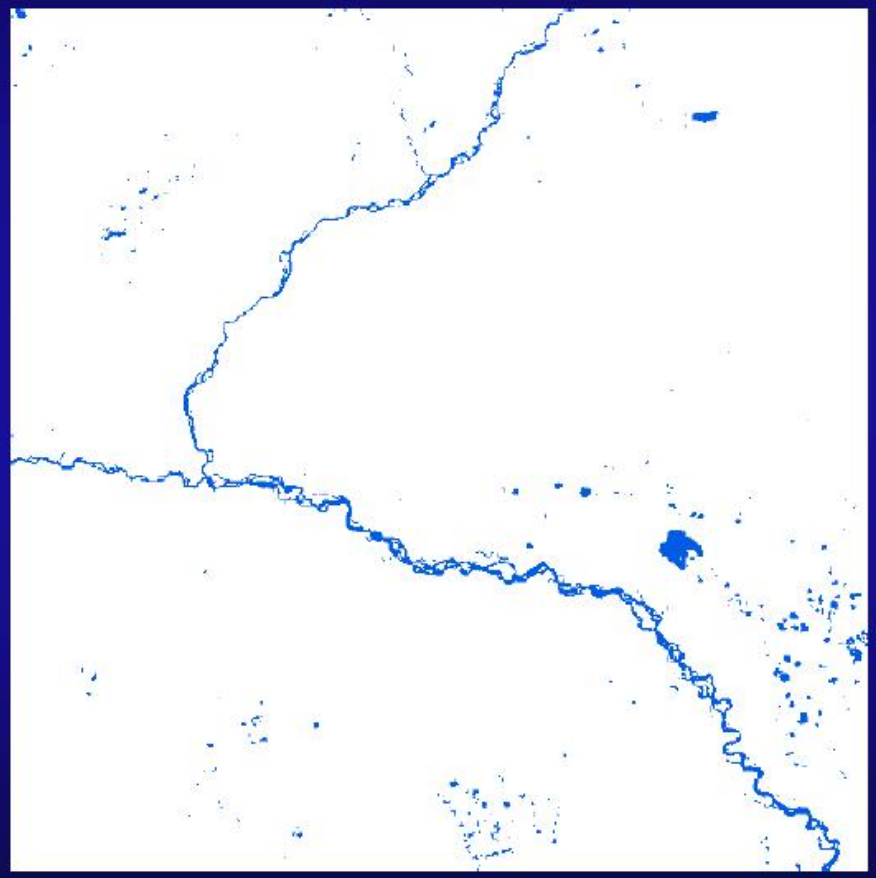
Surface Water Extent

Using top of atmosphere reflectance values,
IF ((NDVI < 0.1) OR ((Indsr(4) < 400) AND (Indsr(5) < 500)))





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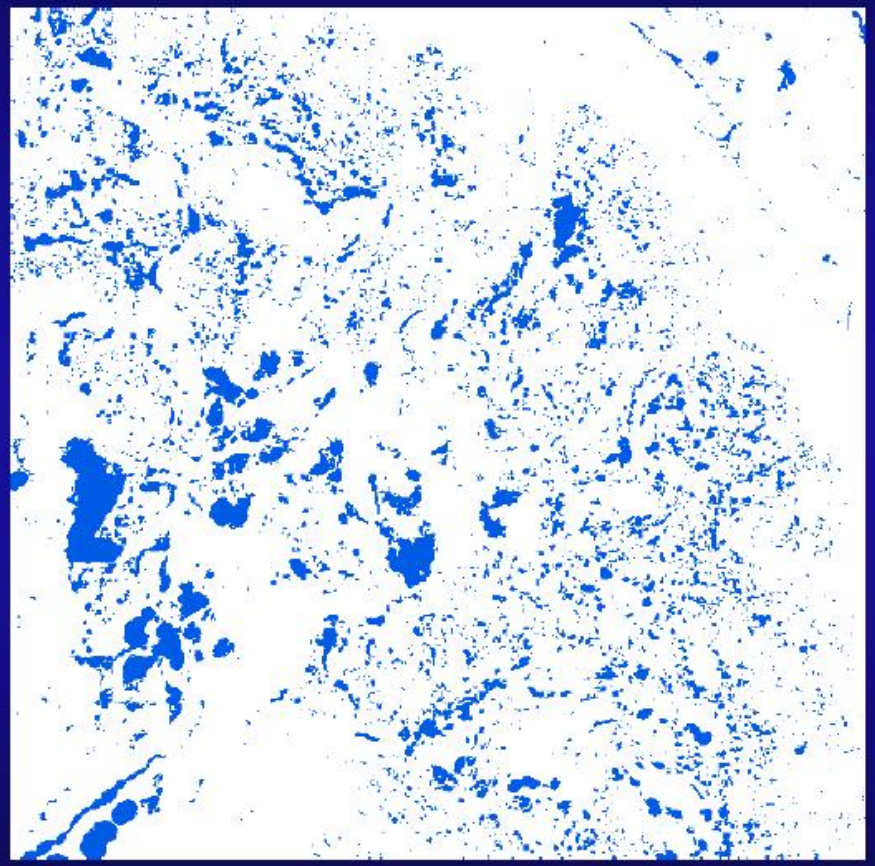

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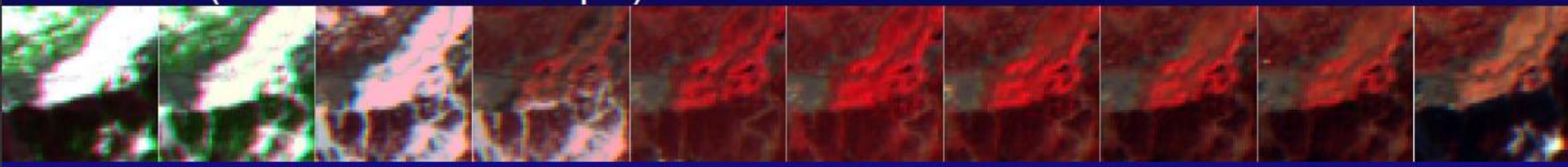
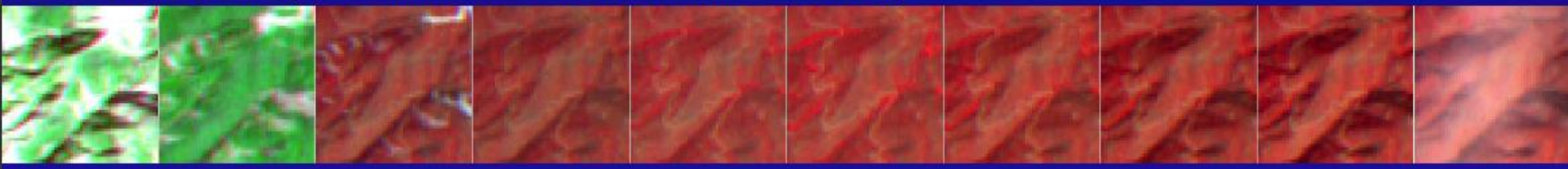
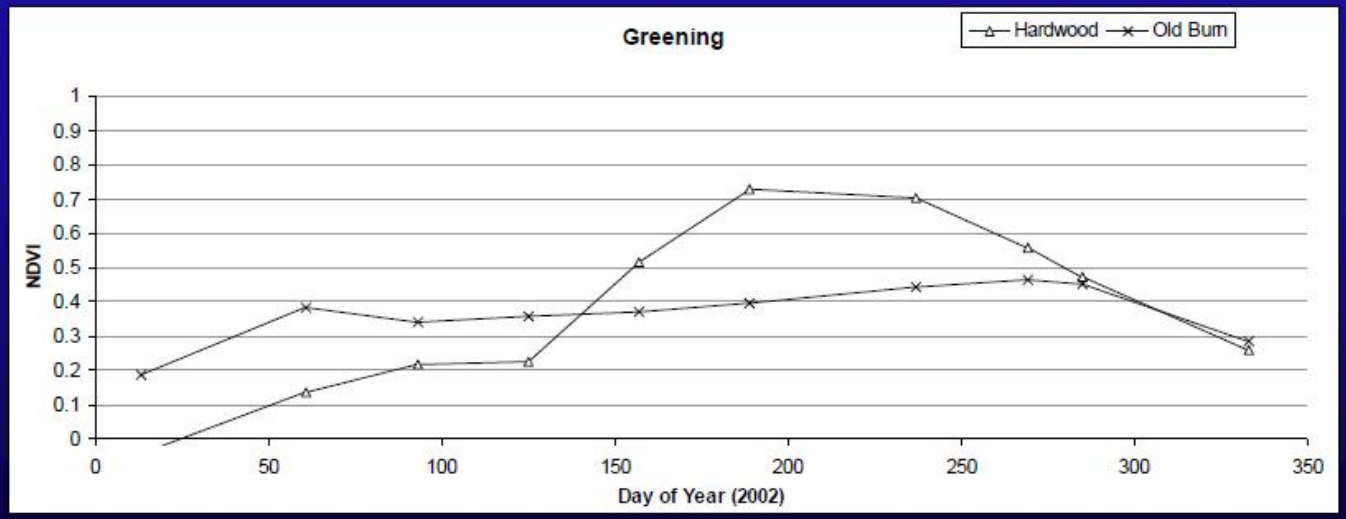
Vegetation Condition, Lake Tahoe area

Hardwood (snow covered until April):



Old burn scars (with thin cloud in November scene):





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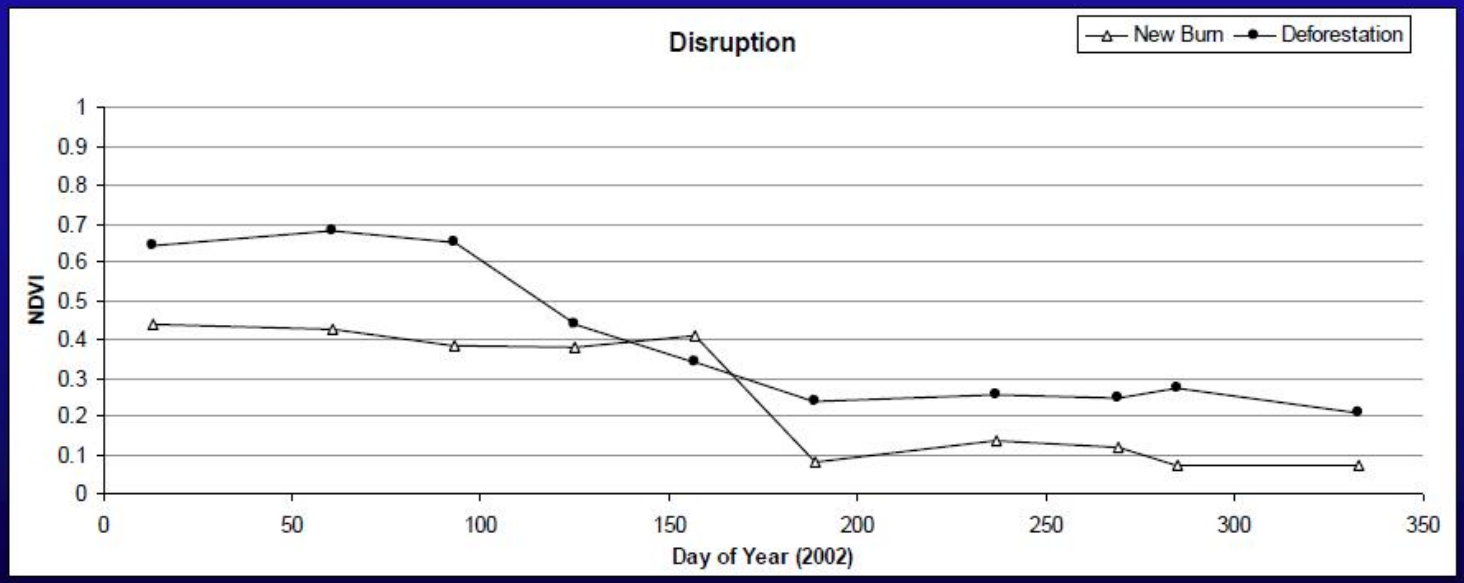
Monitoring Forest Health

Effects of logging operations:

Effects of Cannon Fire near Walker, CA, in mid-June, 2002:



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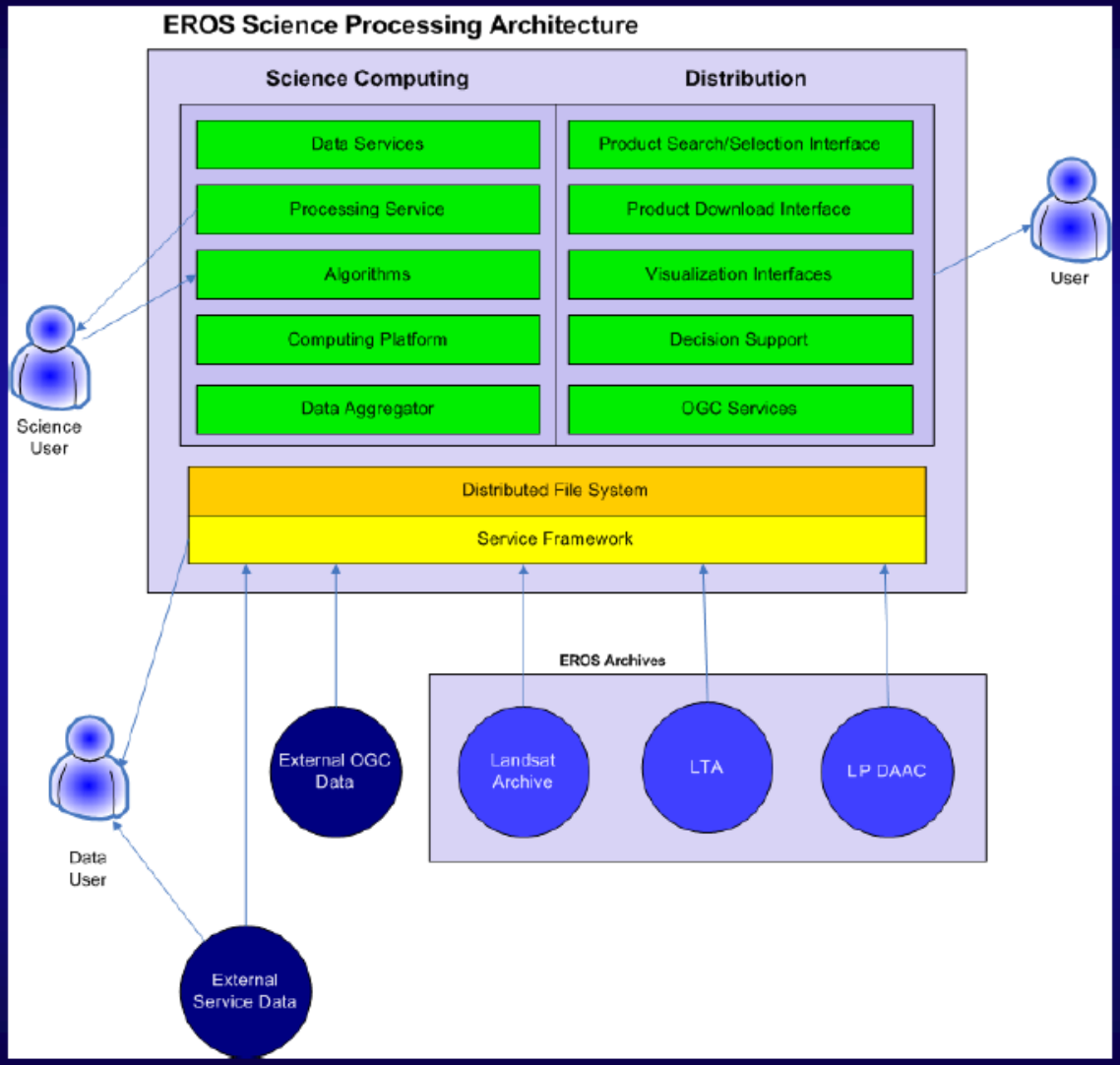
Standard Architecture - ESPA



EROS Science Processing Architecture

- Service Framework provides a standard processing infrastructure that optimizes software re-use.
- Basic functions, procedures, interfaces, and software that support generation of higher-level products.
  - Data access
  - Science computing
  - Product distribution
- Algorithms can be chained together to build processing workflows
  - Stable and consistent products over time

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ESPA Provides

- Standard SOA interface for software services that can be utilized for science processing
- Standard Storage architecture (distributed file system) for data storage
- Computing platform resources for executing processing algorithms
- Algorithm implementation standards and policies for integrating algorithms into the architecture

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ESPA Provides - Continued

- Processing service for executing processing algorithms in a Service Oriented Architecture
- Data services for querying and storing metadata
- Capability to use existing distribution interfaces for generated products/data
- Capability to use custom services (e.g., OGC) for distributing data

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Vision for the Future

- Provide on-demand processing of archive data to scene-based higher level products (surface reflectance, surface temperature) for all Landsat TM and ETM+ data by launch of Landsat 8
- Operational Processing of WELD composites – extend capability to process all TM and ETM+ data for the U.S. and the globe
- Global land cover – annual continuous fields and 5-year thematic classifications
- Incorporation of algorithms / software in ESPA framework for other products (LAI)

Summary

- Consistent geophysical and biophysical parameters are necessary to achieve successful environmental monitoring capabilities
- Landsat data are routinely used for inventorying and monitoring the land surface at wide ranging scales, for a variety of purposes, and by a diverse community
- Stakeholders require information products – not just data
- Terrestrial monitoring requires a framework of capabilities within which to integrate measurements from multiple observation platforms in order to retrieve the necessary information with which to conduct scientific assessments and inform decision-making