

Refresh Landsat Science Team thinking concerning Landsat Higher Level Products

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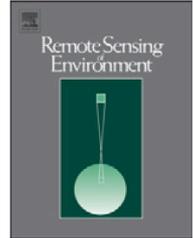




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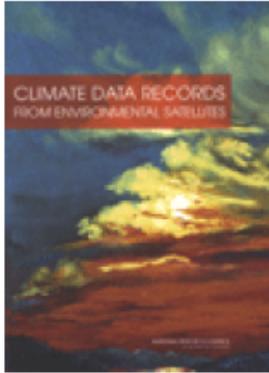
Landsat-8: Science and product vision for terrestrial global change research



- The provision of ‘higher-level’ Landsat products, i.e., geographically seamless, gridded products that have been subject to geophysical transformations and processed to derive environmental variables over different time periods (monthly, seasonal, annual), have been advocated by the LST and by the user community.
- Higher-level products are needed to meet demands for consistently processed, moderate spatial resolution, large area, long-term terrestrial data records for climate and global change studies, to help national and international reporting linked to multilateral environmental agreements, and for regional and national resource management applications.

'Higher-Level' Products

- gridded products
- subject to geophysical transformations and processed to derive environmental variables
- over different time periods (monthly, seasonal, annual etc.)
- can be generated
 - systematically/routinely e.g., MODIS products
 - as one-off's e.g., GlobAlbedo
- application requirements usually different
 - climate data records e.g., NASA AVHRR LTDR
 - near real time monitoring e.g., USDA AVHRR pasture rangeland forage insurance



Climate Data Records from Environmental Satellites: Interim Report

Committee on Climate Data Records from
NOAA Operational Satellites, NRC, 2004

Recommendation: NOAA should build their satellite-based Climate Data Record generation program based on lessons learned from previous attempts, which point out several unique characteristics of satellite Climate Data Records, including

- **Continuing calibration**
- **Validation**
- **Quality Assessment**

- **Algorithm refinements**

- **All leading to periodic reprocessing and reanalysis to improve error quantification and reduce uncertainties.**

Higher Level Landsat Products advocated by the LST and the user community

Successful model: the MODIS Land Products

Energy Balance Product Suite

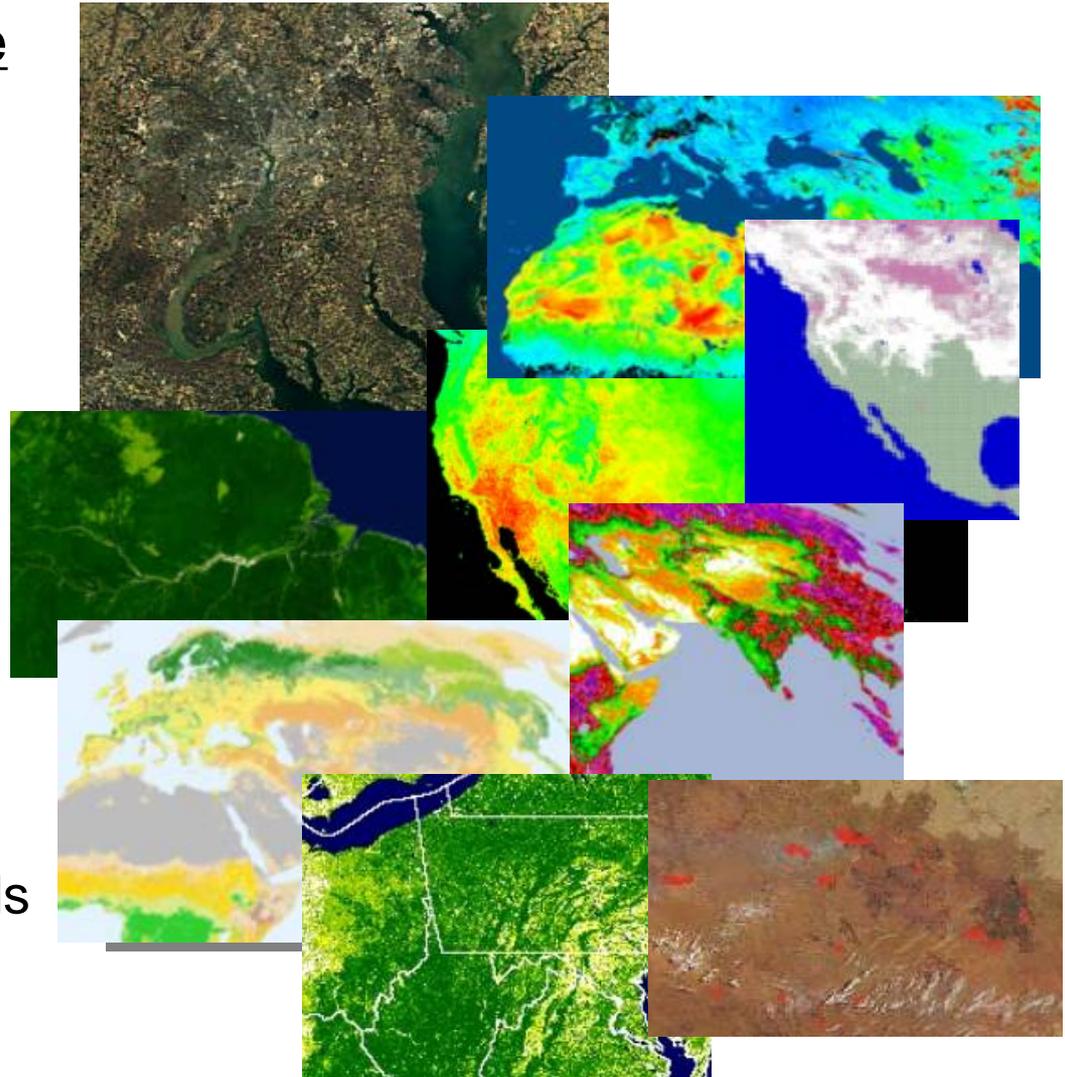
- Surface Reflectance
- Land Surface Temperature, Emmissivity
- BRDF/Albedo
- Snow/Sea-ice Cover

Vegetation Parameters Suite

- Vegetation Indices
- LAI/FPAR
- GPP/NPP

Land Cover/Land Use Suite

- Land Cover/Vegetation Dynamics
- Vegetation Continuous Fields
- Vegetation Cover Change
- Fire and Burned Area



14+ global years of MODIS land products

imminent 5th reprocessing of entire product record (May '00 to present)

Terra, Collection 005

Julian day		16-day Shortwave Broadband White-Sky Albedo (MCD43A3)	16-day Nadir BRDF-Adjusted Reflectance Bands 1,4,3 (MCD43A4)	8-day Land Surface Reflectance Bands 1,4,3 (MOD09A1)	8-day Snow Cover (MOD10A2)	8-day Daytime Land Surface Temperature (MOD11A2)	8-day Land Nighttime Surface Temperature (MOD11A2)	8-day Active Fire Detection (MOD14A2)	8-day Leaf Area Index (MOD15A2)	8-day Fractional Photosynthetically Active Radiation (MOD15A2)	16-day Enhanced Vegetation Index (MOD13A2)	16-day Normalized Differential Vegetation Index (MOD13A2)
2013 281	Q1	Not Available	Not Available									
10/8												
2013 273	Q1											
09/30												
2013 265	Q1											
09/22												
2013 257	Q1											
09/14												
2013 249	Q1											
09/6												
2013 241	Q1											
08/29												
2013 233	Q1											
08/21												
2013 225	Q1											
08/13												
2013 217	Q1											
08/5												
2013 209	Q1											
07/28												
2013 201	Q1											
07/20												
2013 193	Q1											
07/12												
2013 185	Q1											

Science Needs for derived satellite products

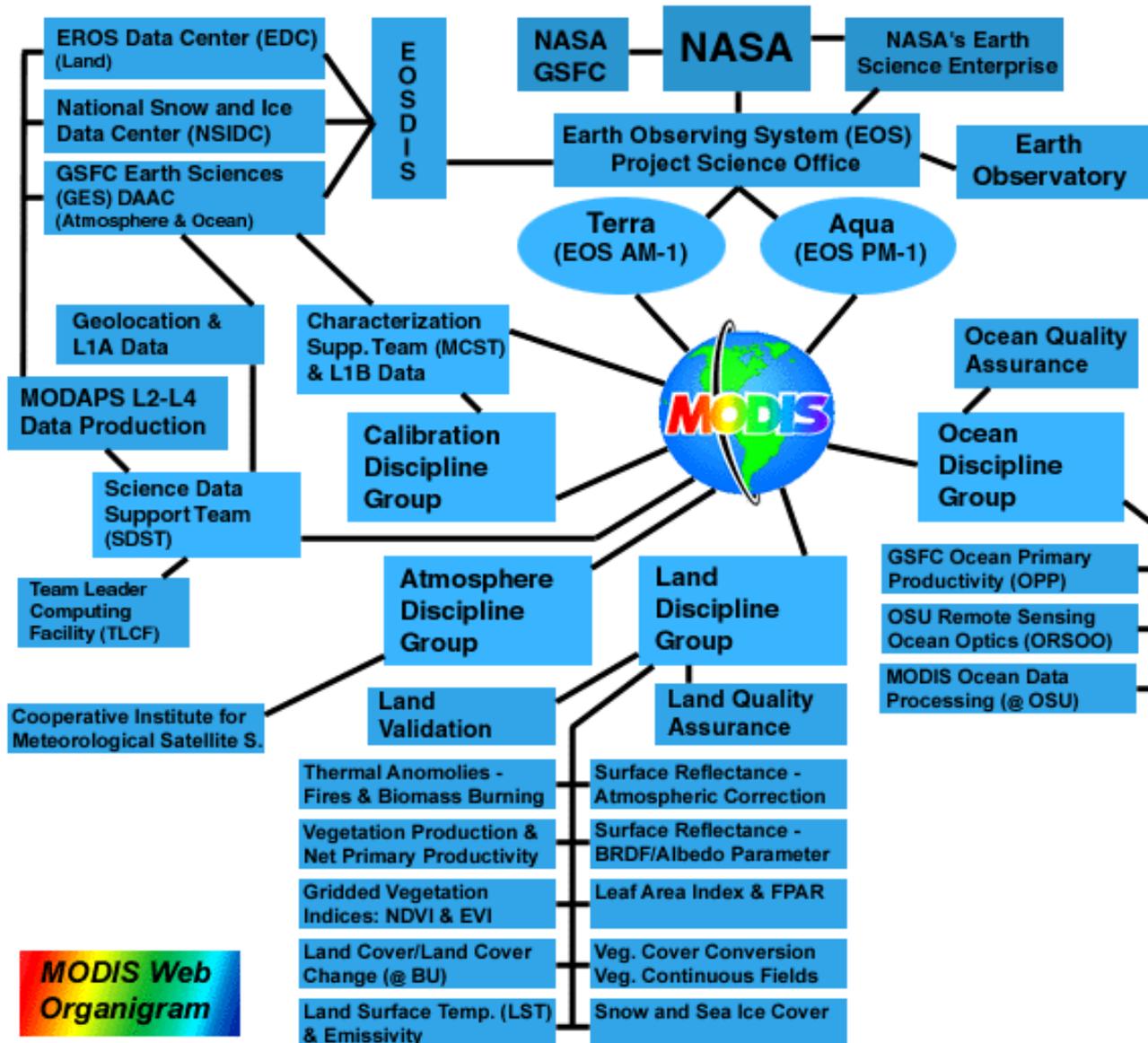
- Algorithms
 - recent, peer-reviewed, responsive to science community requirements
 - taking advantage of improved sensing technology
- Standardized products
 - format
 - filename convention
 - content structure (e.g., data layers, metadata etc.)
 - documentation
 - versioning (perhaps also collections)
- Systematic production on dedicated computing facility, allowing
 - long term global production
 - sophisticated pre-processing and use of ancillary data sets
 - reprocessing to achieve stability of products over long time periods
 - production efficiencies (e.g., for products that share common inputs)
- Dedicated scientists & support staff to
 - develop, code, and document algorithms & products
 - monitor/define product quality and product accuracy
 - refine algorithms as needed
 - develop software tools for product manipulation
 - weekly telecons

Science Needs for derived satellite products

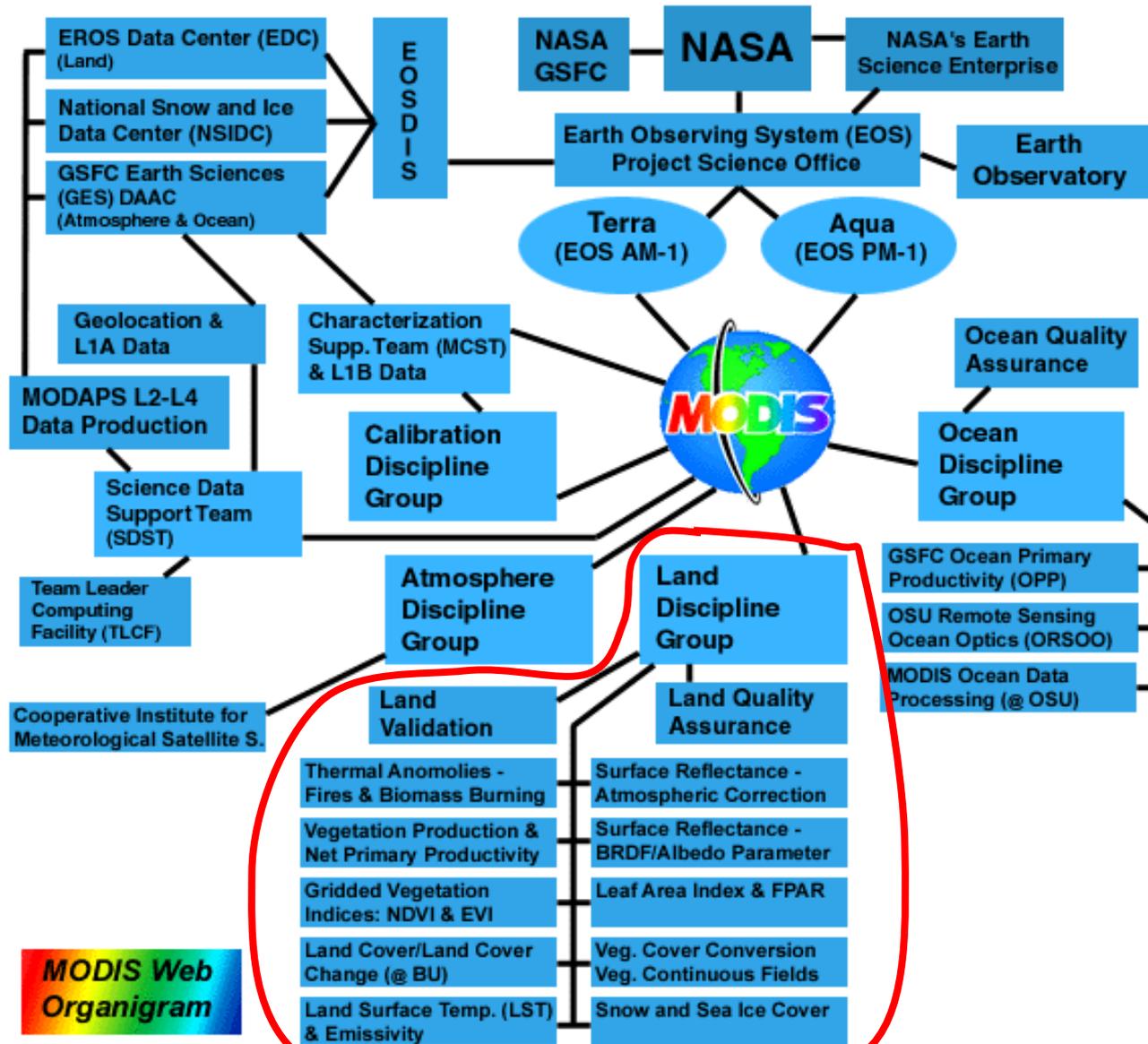
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**Where, the Landsat
ST is currently at ?**

MODIS Science Team Organization & Products



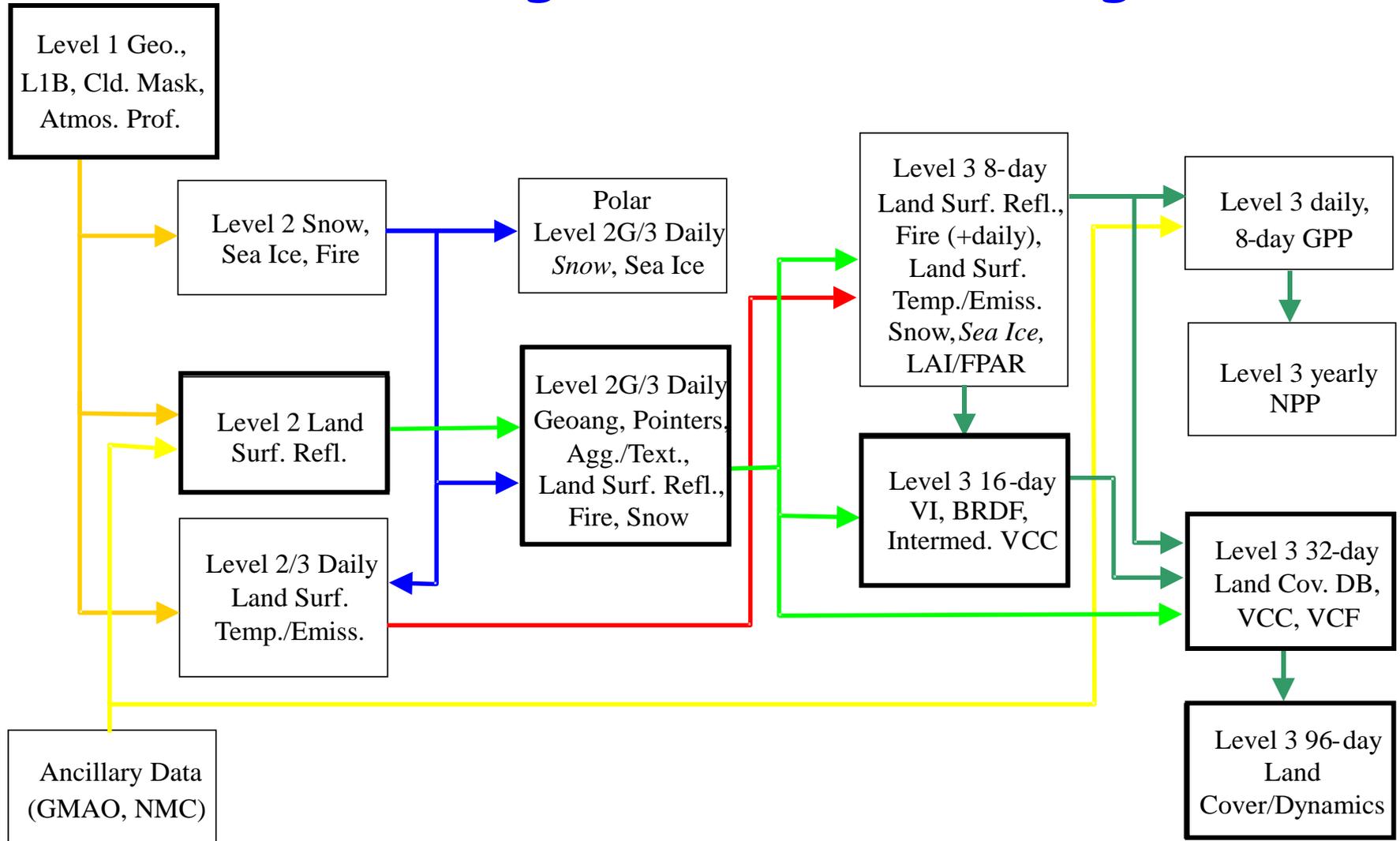
MODIS Science Team Organization & Products



MODIS land product organization

- The Science Team are responsible for developing the science algorithms and processing software used to produce one or more of the MODLAND products, they have Science Computing Facilities (SCF)
- The processing software are run in a dedicated production environment
 - the MODIS Adaptive Processing System (MODAPS)
 - located at NASA Goddard Space Flight Center (GSFC)
- The standard MODLAND products generated by the MODAPS are sent to
 - Distributed Active Archive Centers (DAACs) in the US for
 - product archival
 - product distribution to the user community

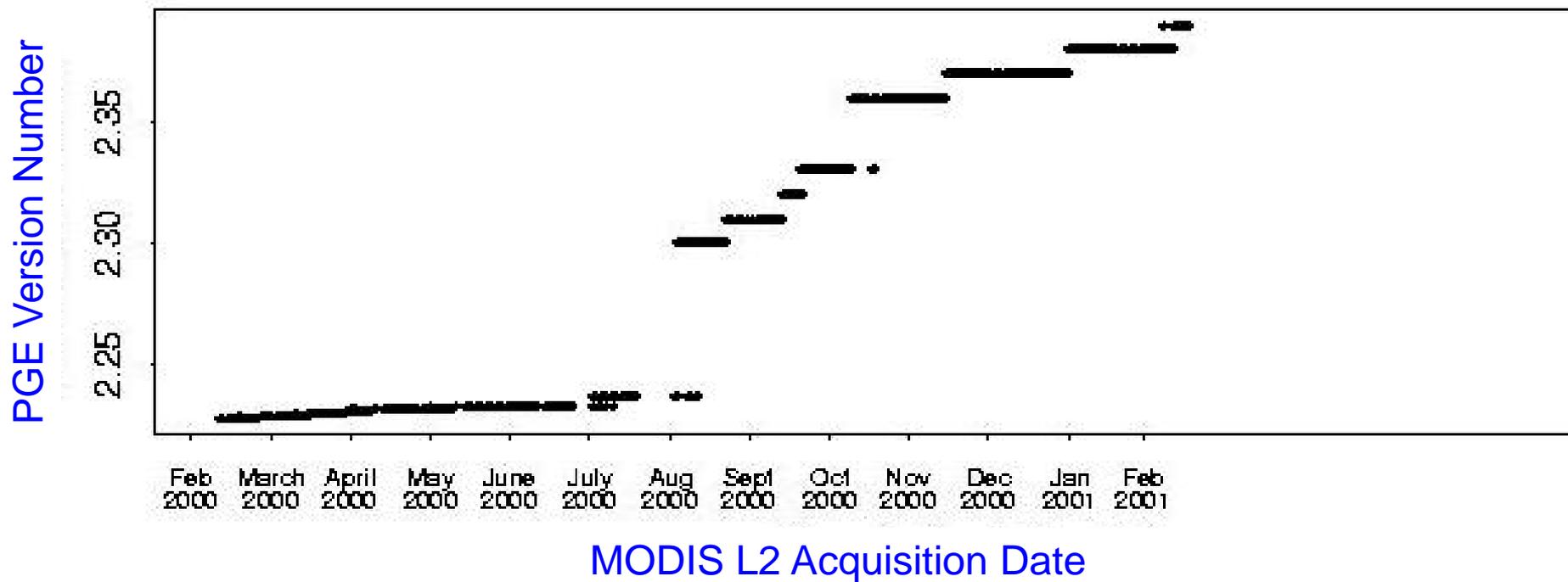
MODIS Land Production High Level Processing Chart



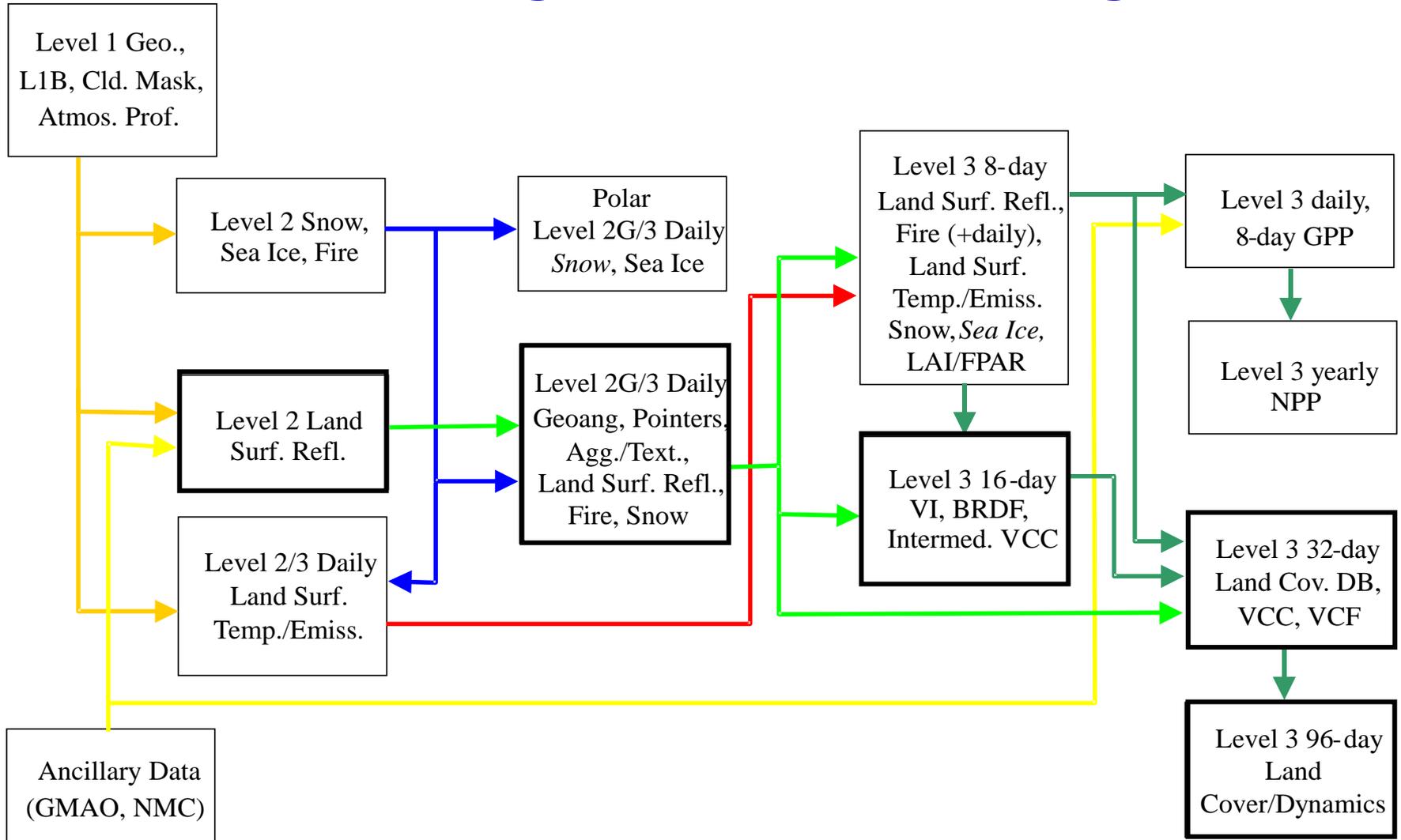
Processing driven by Production Rules running in a scheduling system

- Processing Period
 - 5 min. granules
 - orbit processing
 - 1, 8, 16, 32, 96 day products
 - yearly products
- Required and optional inputs
 - precursor (upstream) products
 - precursor (upstream) ancillary data
 - Level 2 granules intersecting Level 3 tiles
 - how long to wait for missing inputs
- Start of period
 - reset at beginning of year
 - 2-3 day overlap at end of year

Software Changes: the MODIS land surface reflectance code was updated more than once per month in the first year of MODIS-TERRA data to fix product issues



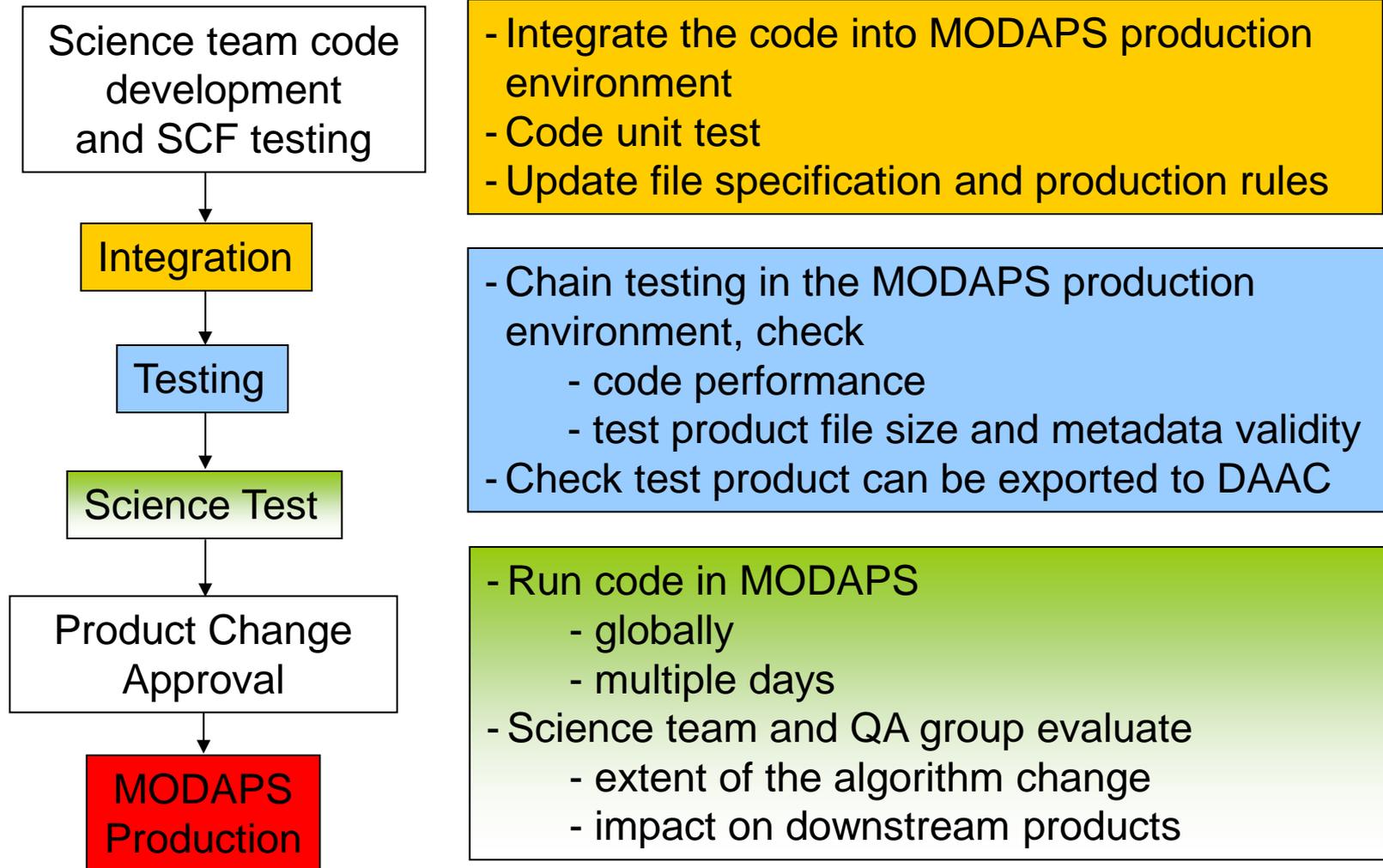
MODIS Land Production High Level Processing Chart



MODIS Land Software Life Cycle

clear boxes = Science Team activities

colored boxes = MODAPS (i.e. production) staff activities



Errors may be introduced at any time during the life of the instrument and may not be identified for a considerable period *e.g.*, Antarctic Ozone Hole

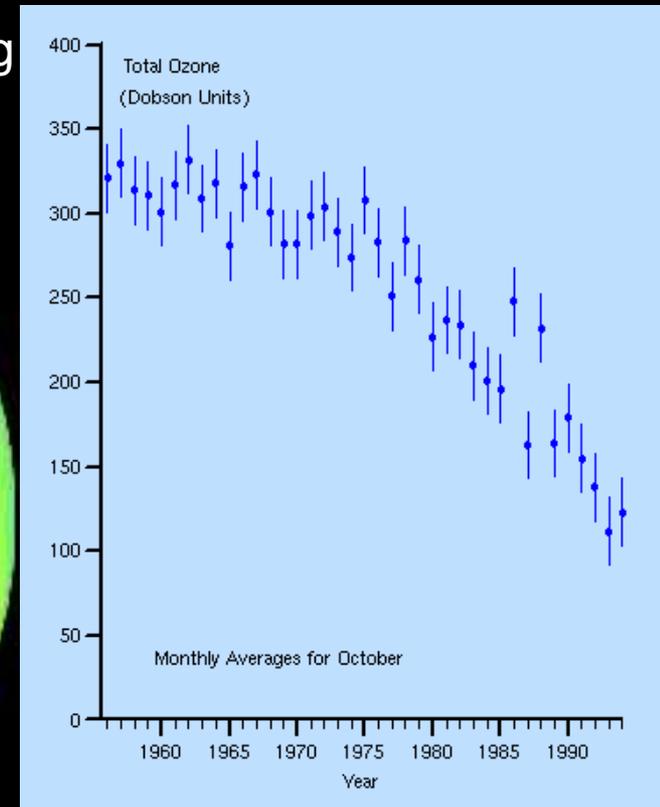
NASA TOMS satellite data didn't reveal the Antarctic ozone hole because the software was programmed to flag low ozone values as bad data.

The hole was discovered by the British Antarctic Survey from data obtained with a Dobson ozone spectrophotometer at Halley Bay station 1981-1983.

Reanalysis of 12 years of TOMS data verified the existence of the hole and indicated that it had grown rapidly for that period over most of Antarctica.

Data from additional instruments revealed ChloroFloroCarbons (CFCs), such as Freon, destroyed the ozone layer and created the hole.

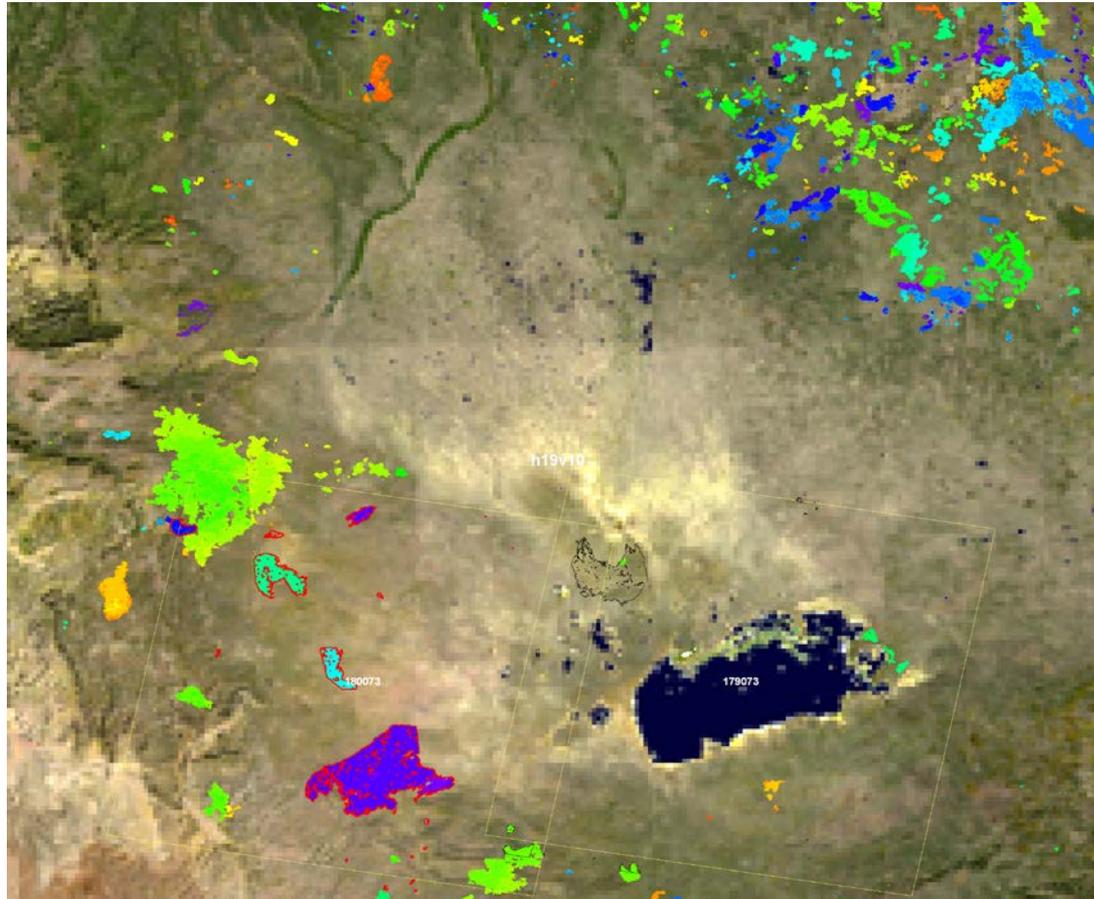
Oct 1, 1998



A Dobson Unit is equal to 1/100 mm, (the thickness that the ozone layer would have if the overhead column were brought down to the surface).

Sources of Satellite Product Error

Example -Stupid Coding Error (by David Roy)



Collection 5.0
MODIS burned area
product (MCD45)

Burned area emission errors
occur at pixels where the
3.66-3.84 μm (band20)
MODIS brightness
temperature is greater than
327.67 K.

This bug took ~3
years to be
discovered.

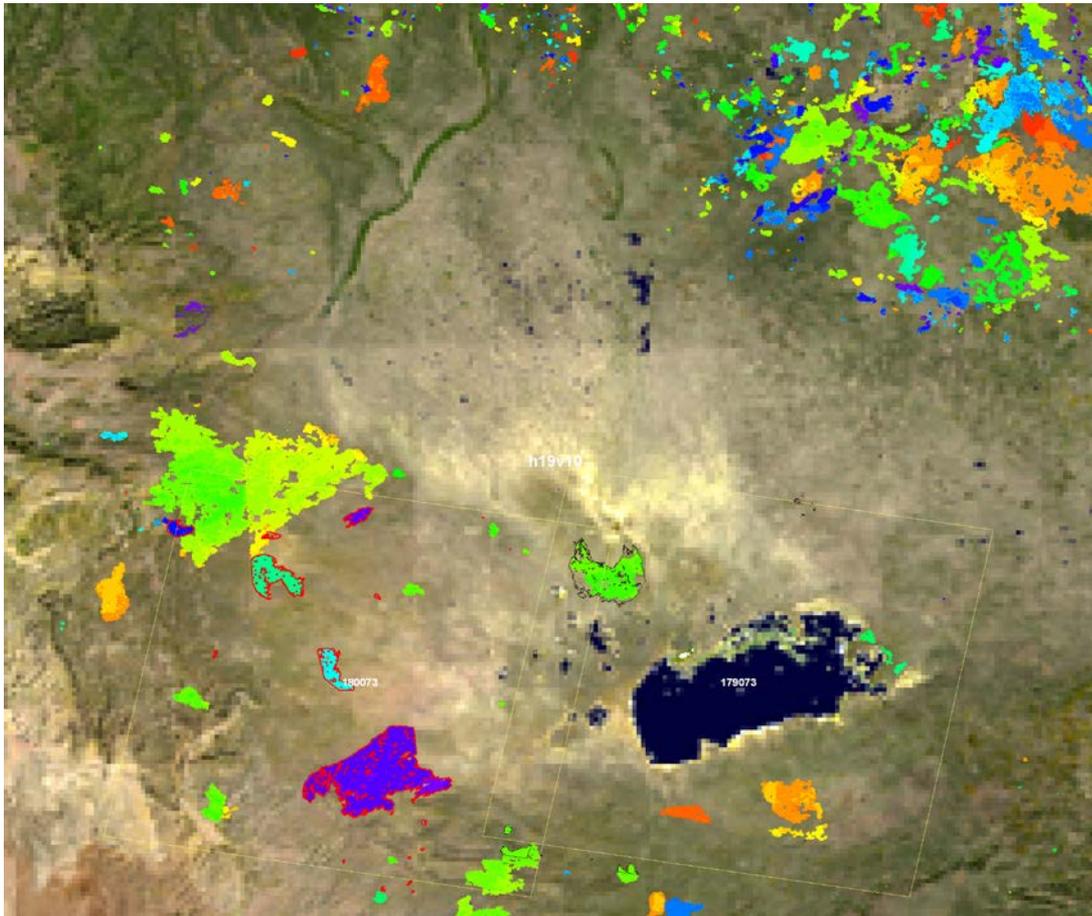
CAUSE: the pixel values brightness temperature*100 are stored as Unsigned Integers (a number 0-65535) but were *incorrectly* read into the MODIS burned area algorithm as Signed Integers (number 0 to +/- 32767). Thus, values >32767 were converted by this inconsistency in the burned area code to negative values and so were considered very cold and could not possibly be burns.

Sources of Satellite Product Error

Example - Stupid Coding Error Fixed

MODIS burned area product

Map many more burns



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Some Lessons Learned From Bulk Landsat Science Data Processing
Summary Slide from a David Roy presentation at the
Landsat Science Team, USGS EROS Center, Sioux Falls, August 16-18 2011

- **You cannot hit a *big red button* to make reliable large area and/or long term Landsat higher level science data products**
- Get the product out early, Ensure mechanisms to involve the user community in product QA
- Routinely QA the input data with validation
- Reprocess products as needed
- Implement and manage a product versioning scheme
- Science algorithms developed on individual scenes don't necessarily provide consistency between scenes
- Product Quality Assessment challenge increases with data volume, algorithm complexity and product dependencies
- Expect schedule creep in Science Product Development

Some Landsat Product Discussion Bullets

- What Products & Why & Applicable to the US Landsat archive
- L1T improvement products
- Analysis ready products
- Higher-level products, including
 - climate data records
 - change products
 - near real time applications
- Systematically generated (MODIS model) products
- “One-off” products