Use of NASA Data and Capabilities for Monitoring Surface Moisture and Burn Areas

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MT Hydrology Workshop

27-29 July 2010

Helena, MT

NASA's Short-term Prediction Research and Transition (SPoRT) Center

Mission: Apply unique NASA Earth science research and observations to improve the accuracy of short-term (0-24 hr) weather prediction at the regional and local scale – work mainly with WFOs

SPoRT Paradigm

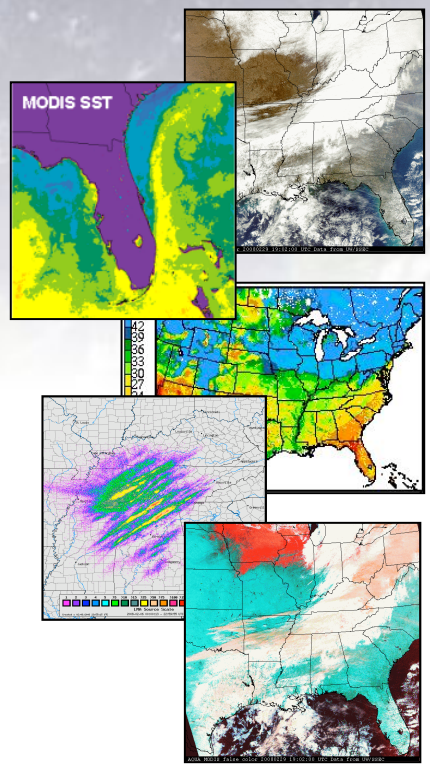
- match observations/capabilities to forecast problems
- develop / assess solution in "testbed", transition to decision support system
- conduct training, product assessment and impact

History

- 1990s: NASA/MSFC and NWS collaborates on local model forecasts of precip
- 2000: NASA launches Terra satellite (MODIS / AIRS) – desired infusion to operations
- 2002: MSFC obtains funding for SPoRT 3 year effort to transition NASA data
- 2003 (Feb): First MODIS image in AWIPS; suite of products to 3 WFOs
- 2003 (Apr): LMA data used to improve lead time for occurrence of severe weather
- 2004: MODIS suite provided to Great Falls, MT, included False Color Snow product
- 2006: MODIS suite expanded to SR coastal WFOs – SST Composite developed
- 2007: Initialization with MODIS SSTs and AIRS profiles improves forecasts
- 2008: Over 30 products from MODIS, AMSR-E, AIRS, NALMA, in AWIPS - 15 WFOs
- 2009: SPoRT participates in HWT Spring Experiment as part of the GOES-R PG
- 2009: MODIS SSTs incorporated into V3 of WRF EMS
- 2010: MODIS data in AWIPS2

Science Mission Directorate
National Aeronautics and Space Administration

NASA's Short-term Prediction Research and Transition (SPoRT) Center



Situational Awareness (*MODIS, AMSR-E, Lightning Arrays*)

- timing and location of severe weather
- morning minimum temperatures (local variations)
- detection and monitoring of fog, smoke, fires

Modeling (*WRF-EMS, NASA/LIS, microphysics*)

- coastal weather processes (sea breeze convection / temperatures)
- development / movement of off-shore precipitation processes – tropical systems

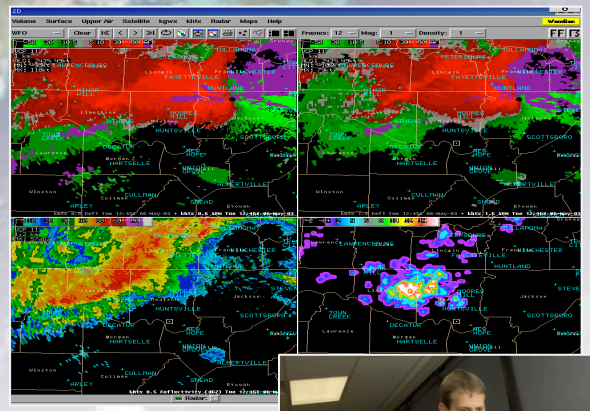
Data Assimilation (*AIRS profiles, Optimal Interpolation, ADAS*)

- gap filler in data void regions – "atmospheric rivers"

Data and Transition (*DSS, Training, Assessment*)

- AWIPS II plugin development
- Web-based training modules (in NOAA/LMS)
- Intensive Observing Periods (IOPs) with WFOs

Partnerships



Primary

- NWS Southern Region WFOs, TFX
- NOAA NESDIS
- Joint Center for Satellite Data Assim.
- NASA/JPL
- GOES-R Proving Ground
- NASA/GSFC

Other

- NOAA Hazardous Weather Testbed
- NSSL
- Private Industry (e.g. WorldWinds)

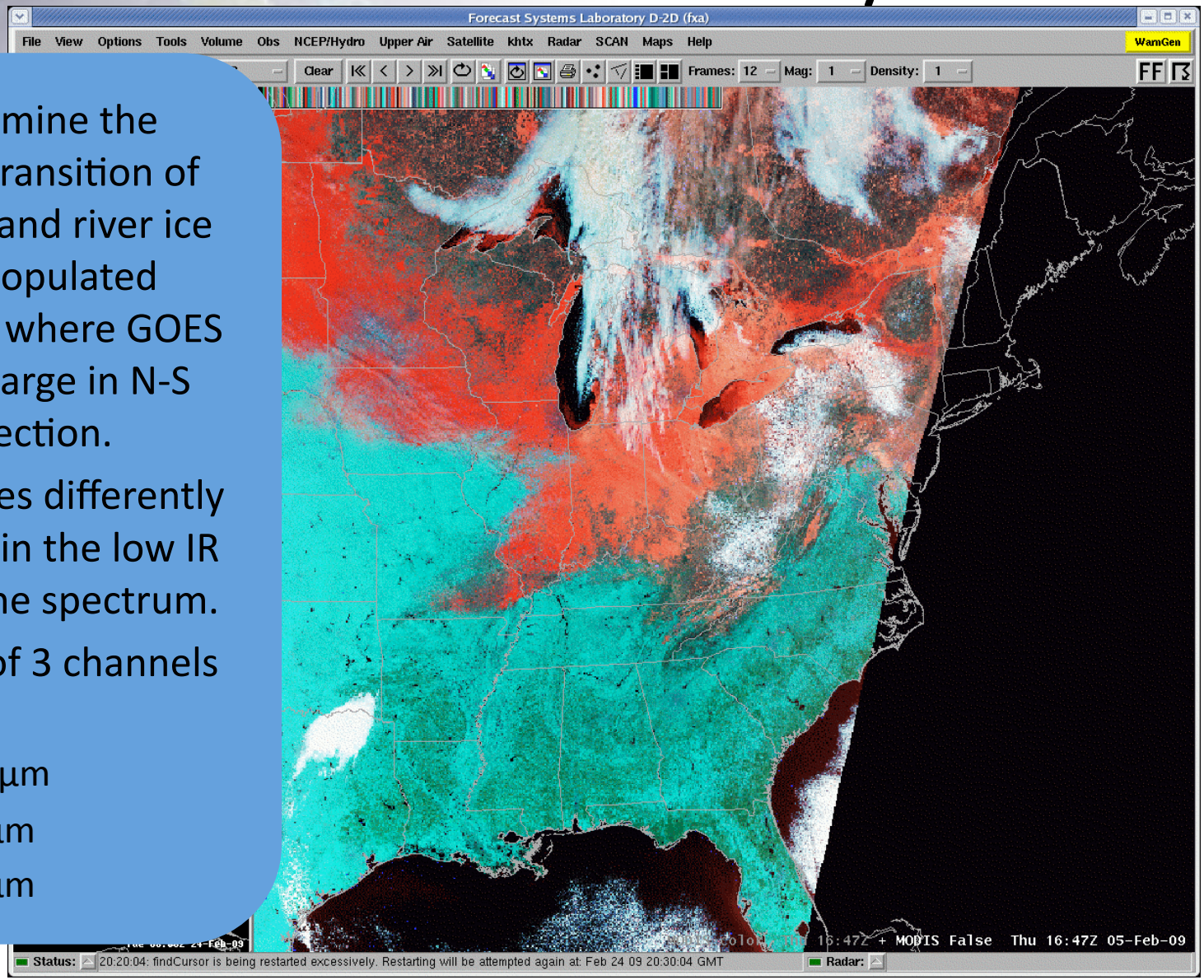
Developing

- NWS Eastern / Central – Great Lakes
- NWS WR

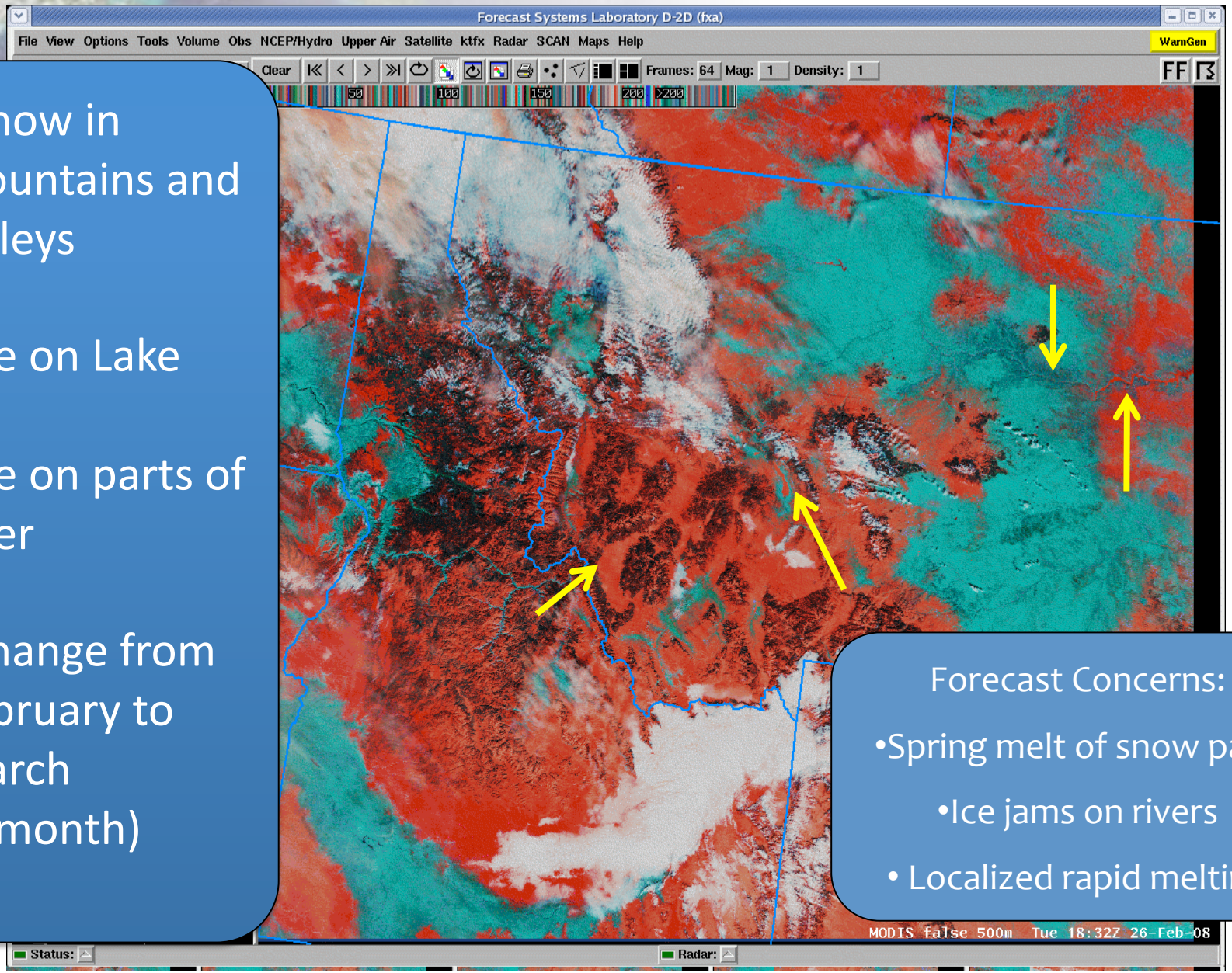
SPoRT website
http://weather.msfc.nasa.gov/sport
Wide World of SPoRT Blog
http://www.nsstc.uah.edu/sportblog/
Collaborative discussion on Facebook
http://www.facebook.com/NASA.SPoRT

MODIS False Color - Snow/Ice

- Need: Determine the extent and transition of snow cover and river ice in rural, unpopulated areas of MT where GOES footprint is large in N-S and E-W direction.
- Snow radiates differently than clouds in the low IR portion of the spectrum.
- Composite of 3 channels at 500 m
  - Vis: ~0.6 µm
  - IR: 1.63 µm
  - IR: 2.13 µm



MODIS False Color

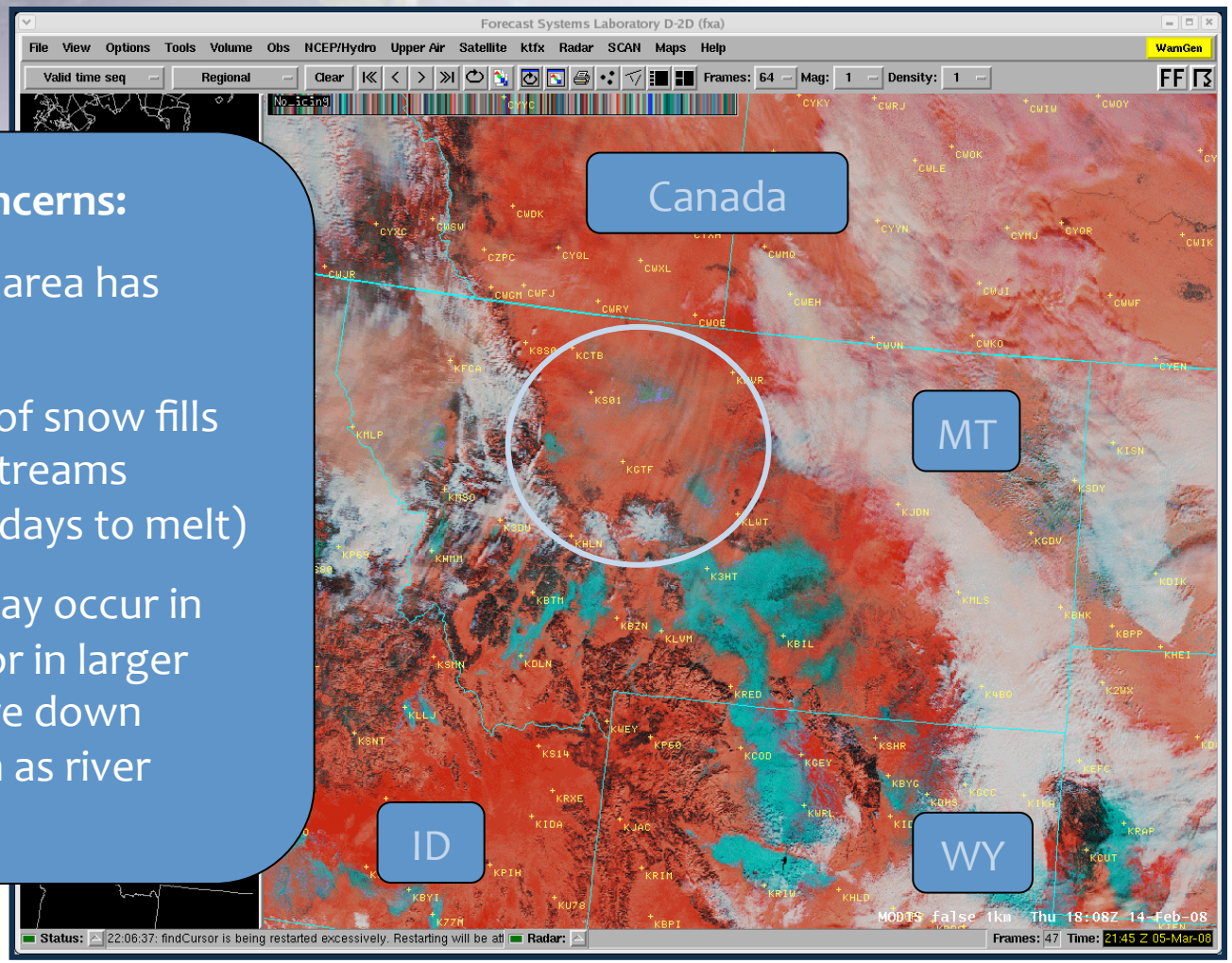


- Snow in mountains and valleys
- Ice on Lake
- Ice on parts of river
- Change from February to March (1 month)

Forecast Concerns:

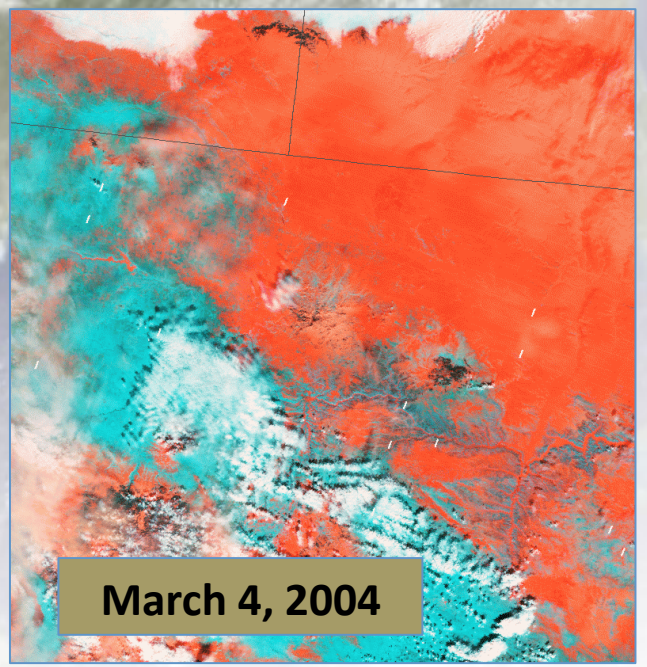
- Spring melt of snow pack
- Ice jams on rivers
- Localized rapid melting

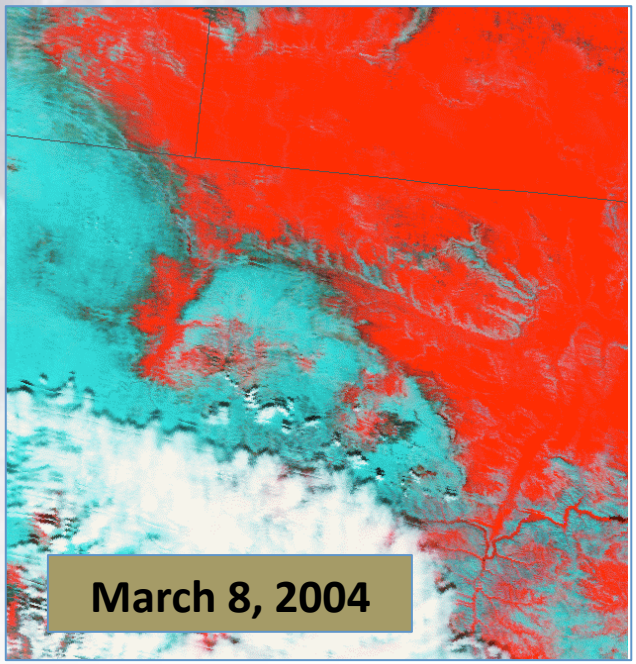
MODIS False Color - GFX



Forecast Concerns:

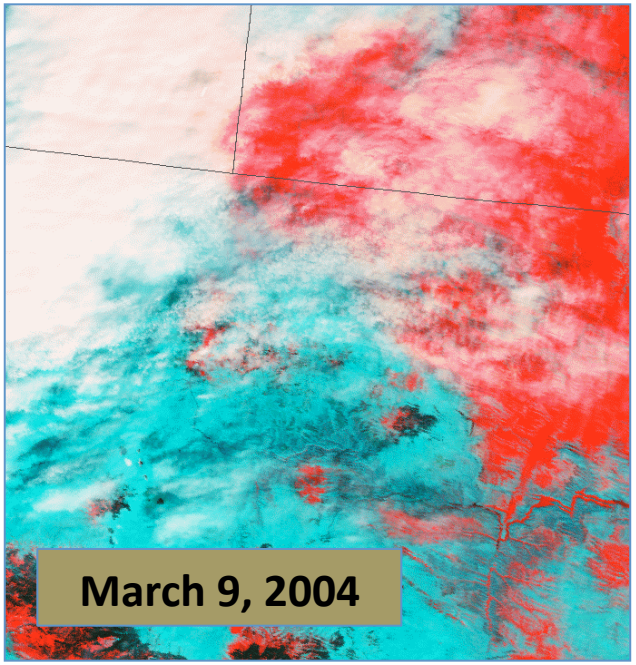
- How much area has melted?
- Rapid melt of snow fills creeks and streams (only took 2 days to melt)
- Flooding may occur in small areas or in larger areas that are down stream, such as river valleys

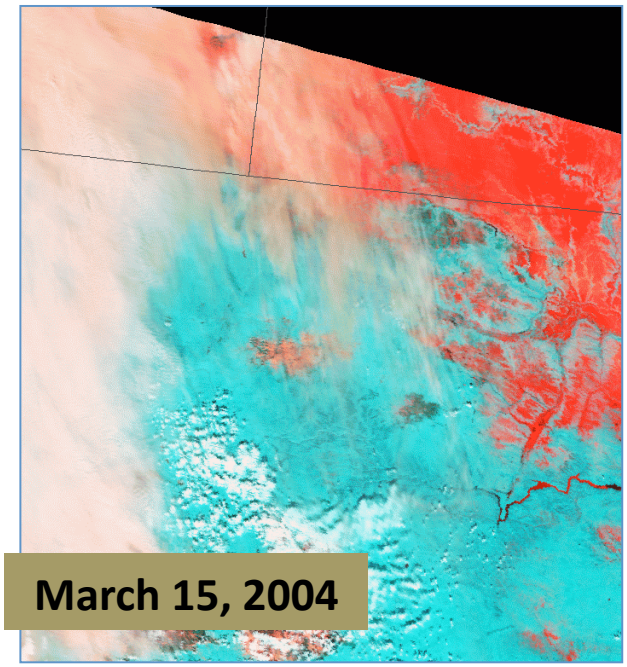




Melting first occurred south of Milk and Missouri Rivers

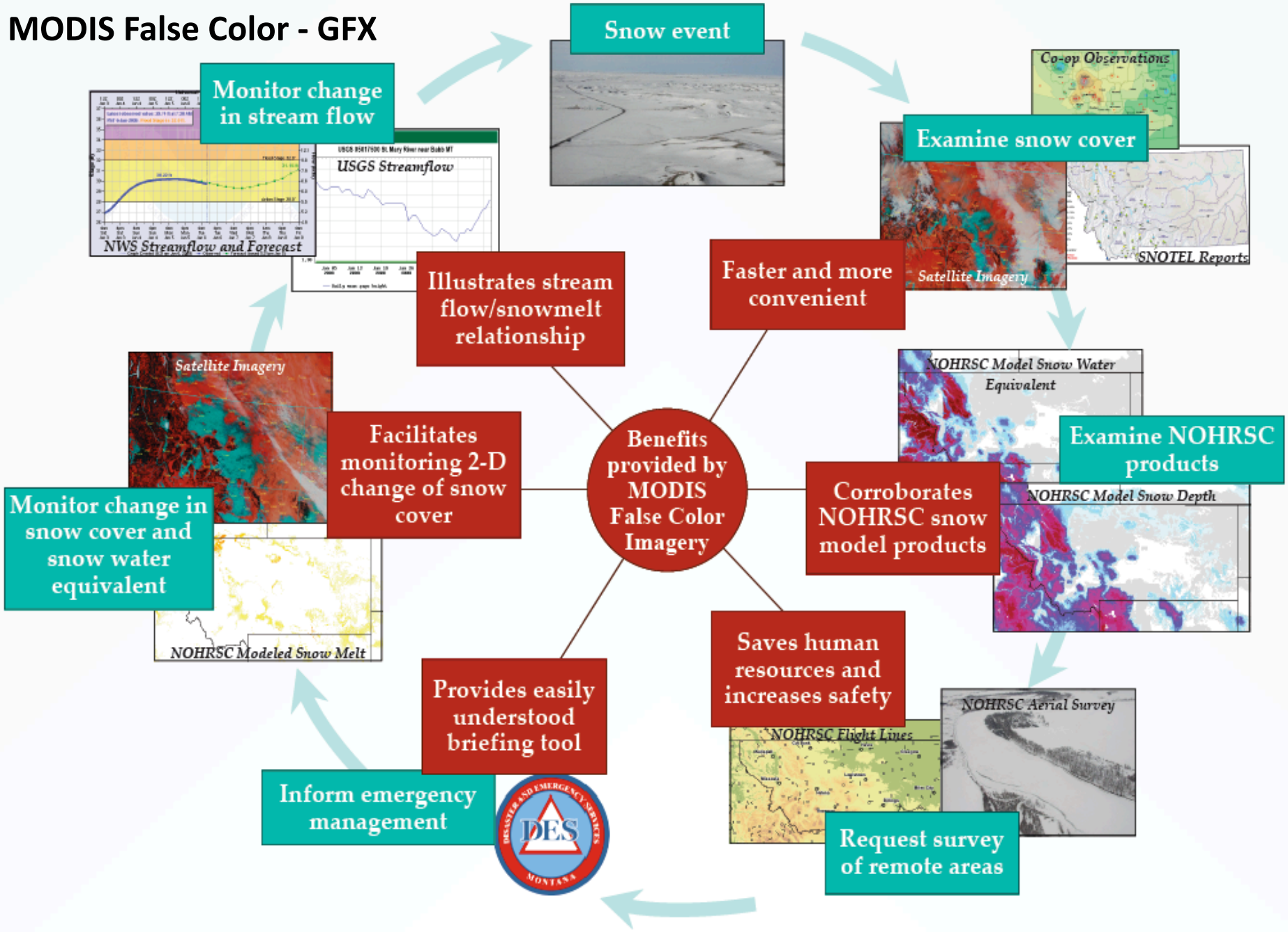
Observation of gradual melting trend indicated less flooding potential than model forecast had suggested.





Assessment of Flooding Potential

MODIS False Color - GFX



NASA Land Information System
Background Information & MT Testrun

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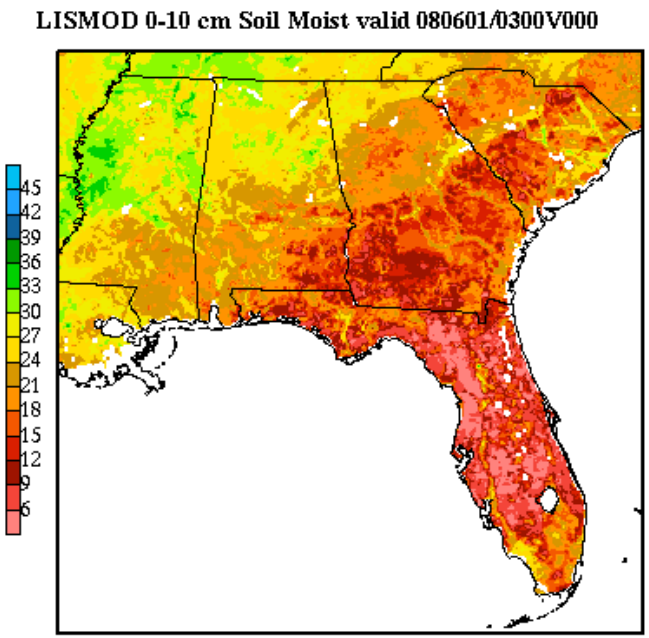
Outline

- Background on the Land Information System (LIS)
  - What is LIS?
  - How does LIS operate?
  - LIS configuration for Montana 2004 output
- Sample 1-km LIS Output over Montana

NASA Land Information System (LIS)

- High-performance land surface modeling and data assimilation system
  - Runs a variety of Land Surface Models (LSMs)
  - Combines satellite, ground, and reanalysis data to integrate LSM in offline mode
  - Can run coupled to Advanced Research WRF
  - Data assimilation capability (EnKF) built-in
    - Plugin framework enables easy substitution of datasets, LSMs, forcings, etc.



- SPoRT experience with LIS
  - Positive impacts to WRF forecast of sea breeze over FL
  - Modest improvement to forecast of air-mass convection in the Southeast using object based verification.
  - Providing LIS output to Birmingham WFO as a diagnostic tool for convective initiation.

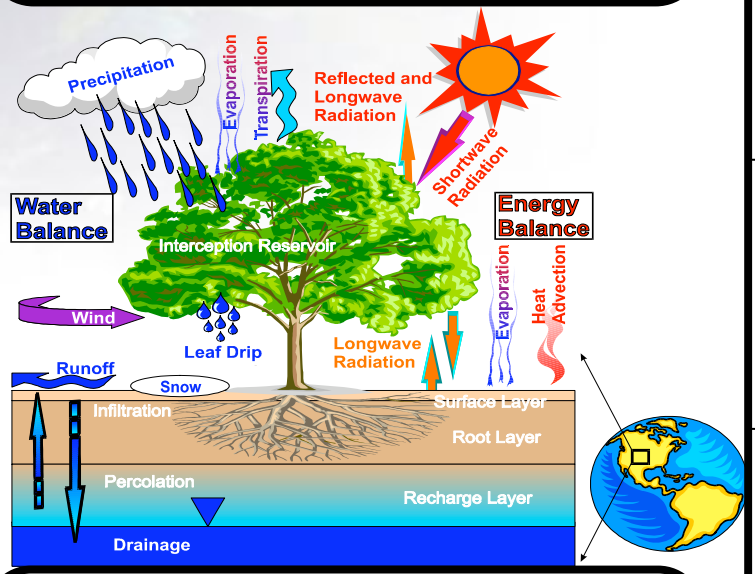
Land Surface Modeling with LIS

Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorology (Atmospheric Forcing)
- Snow Soil Moisture Temperature

Physics

Land Surface Models (e.g. **Noah**, VIC, SIB, SHEELS)



Data Assimilation Modules

Outputs

- Soil Moisture & Temp
- Evaporation
- Runoff
- Snowpack Properties

Applications

- Weather/ Climate
- Water Resources
- Homeland Security
- Military Ops
- Natural Hazards

Land Surface Modeling with LIS

Inputs

Topography, Soils

Land Cover, Vegetation Properties

Meteorology (Atmospheric Forcing)

Snow
Soil Moisture
Temperature

Physics

- 1-km topography, averaged for coarser resolution grids
- Bottom soil temperature: 6-yr climo
- Soil type:
  - 1-km, 19-class State Soil Geographic database
  - Dominant soil type used for grid spacing > 1 km

Data Assimilation Modules

Outputs

Snowpack Properties

Applications

Weather/ Climate

Water Resources

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Natural Hazards

Land Surface Modeling with LIS

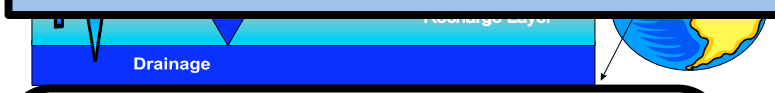
Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorology (Atmospheric Forcing)
- Snow Soil Moisture Temperature

Physics

Land Surface Models

- Vegetation/land cover:
  - 1-km, 24-class USGS
  - Monthly green veg fraction (0.15°)
  - Derived from 1992-93 AVHRR data
- 1-km Land mask → Determined off of vegetation type
- Quarterly and max snow (MODIS) albedo



Data Assimilation Modules

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Land Surface Modeling with LIS

Inputs

- Topography, Soils
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- Meteorology (Atmospheric Forcing)
- Snow Soil Moisture Temperature

Physics

Land Surface Models (e.g. **Noah**, VIC, SIB, SHEELS)

- Datasets driving LSM physics:
  - Input variables: 2-m T, q, sfc pressure, 10-m wind, downward short/longwave radiation, precipitation
  - Forcing sources used by SPoRT/LIS:
    - Global Data Assimilation System (GDAS, GFS assimilation cycle)
    - North American Land Data Assimilation System (NLDAS)
    - Stage IV precipitation analyses
    - GFS forecasts (for same-day predictions)

Outputs

Soil Moisture & Temp

Applications

- Weather/ Climate
- Water Resources
- Homeland Security
- Military Ops
- Natural Hazards

More Info on LIS Atmospheric Forcing

- NLDAS: 1/8 deg resolution (~14 km)
  - Complete suite of variables needed by LIS
  - Hourly reanalyses produced operationally at NCEP
  - Available on NCEP server about 2-3 days after real time
- GDAS: Currently 0.313 deg resolution (~35 km)
  - Complete suite of variables needed by LIS
  - 0-h to 9-h, 3-hourly analysis/forecast flux files from GFS assimilation cycle
  - 2000-2002: (78 km); 2002-2005: (52 km); 5/31/2005-7/27/2010: (35 km); 7/27/10+ (23 km)
  - Available on NCEP server about 6.5 hours after GFS model initialization
- Stage IV: (~4.8 km resolution)
  - Supplemental precipitation forcing
  - NCEP combined hourly radar + gauge product with QC
  - Available on NCEP server about 1-2 hours after real time
- GFS forecasts: (~35 km resolution)
  - Complete suite of variables for "future" LIS output
  - Files available on NCEP server about 4 hours after model initialization time

Possible Output Fields from LIS

Energy Balance	Water Balance	Surface State	Sub-Sfc State	Evapo-ration	Atmos. Forcing	Para-meters
Net SW RAD	Precip. Rate	Snow sfc T	Soil Moisture*	Pot. Evapotr.	Wind	Land mask
Net LW RAD	Evapotrans.	Canopy T	Soil T*	Interc. evap.	Rain	Land cover
Sensible HF	Sfc runoff	Base Soil T	Avg layer liquid SM	Veg. Transp.	Snow	Soil type
Latent HF	Recharge	Avg Sfc T	Avg layer frozen SM	Base Soil Evap.	2-m air T	Sand/Silt/ Clay fractions
Ground HF	Sub-sfc runoff	Sfc RAD T	Total Soil Wetness	Rootzone SM	2-m q_v	Porosity
Fusion energy	Snowmelt	Sfc Albedo	Relative SM	Canopy water Stor.	Sfc Press.	Soil color
Subl. Energy	Delta-soil moisture	Snow water equiv.	Rootzone T	Snow evapo.	Downward SW RAD	Elev. / slope
Advec. Energy	Delta-snow water equiv.	Snow depth		Snow subl.	Downward LW RAD	Leaf /stem area index
Momentum Flx	Delta-sfc water stor.	Snow intercept veg		Snow-free subl.		Snow/max albedo
Delta-heat storage	Delta-intercept stor.	Sfc. Water stor.		Aero/canopy conductance		Greenness veg. fraction

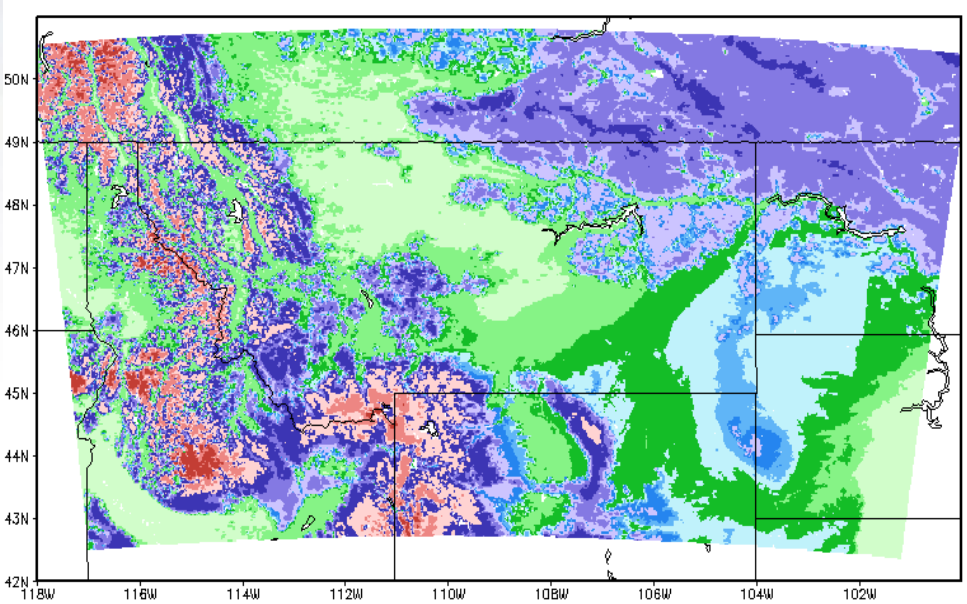
*Multiple levels, depending on land surface model used.

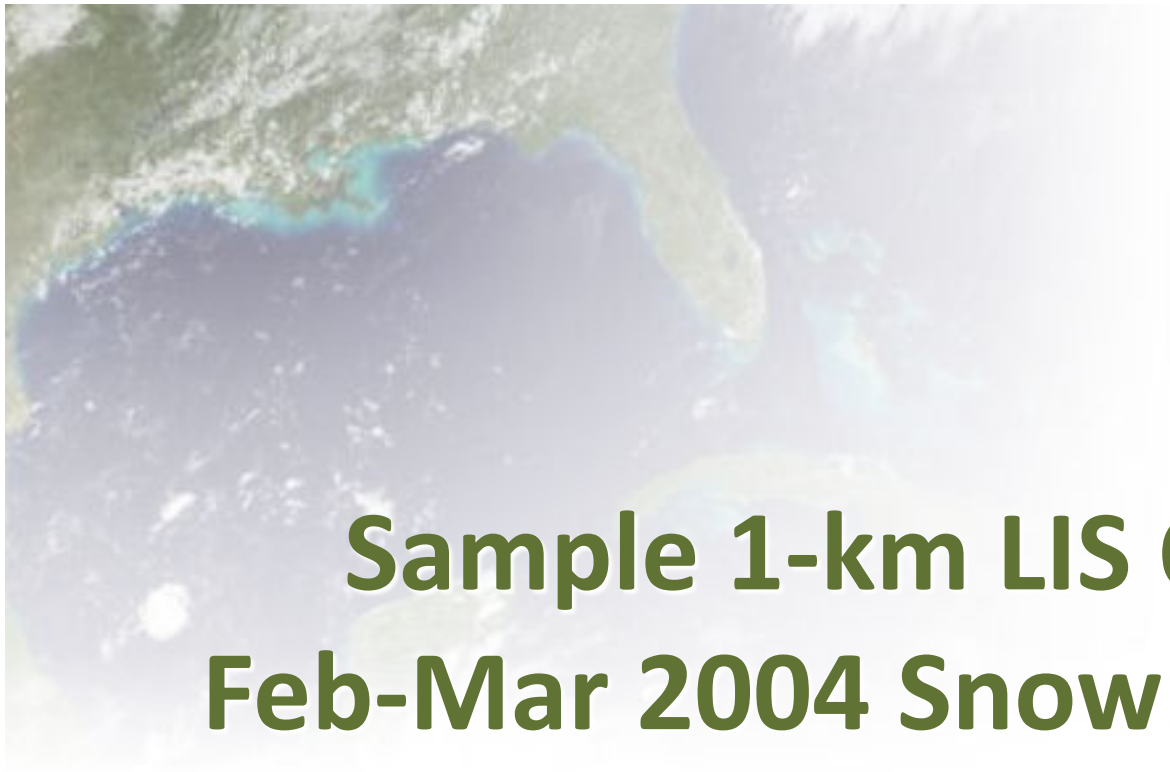
SPoRT Experience with LIS

- Previous SPoRT work with LIS has focused on model initialization experiments:
  - Case et al. (2008) manuscript in *J. Hydrometeor.*
    - Quantified positive impacts to WRF forecasts over Florida by initializing model with LIS land surface output
    - Focused on verification of primary meteorological variables
  - Case et al. (2009) poster: 10th WRF Users Workshop
    - Focused on precipitation verification using traditional and object-based methods
    - Found that 4-km WRF runs initialized with LIS land surface fields improved modestly on forecast air-mass convection
  - Beginning to explore LIS as a potential diagnostic tool

Montana 1-km LIS "Spin-up" Run

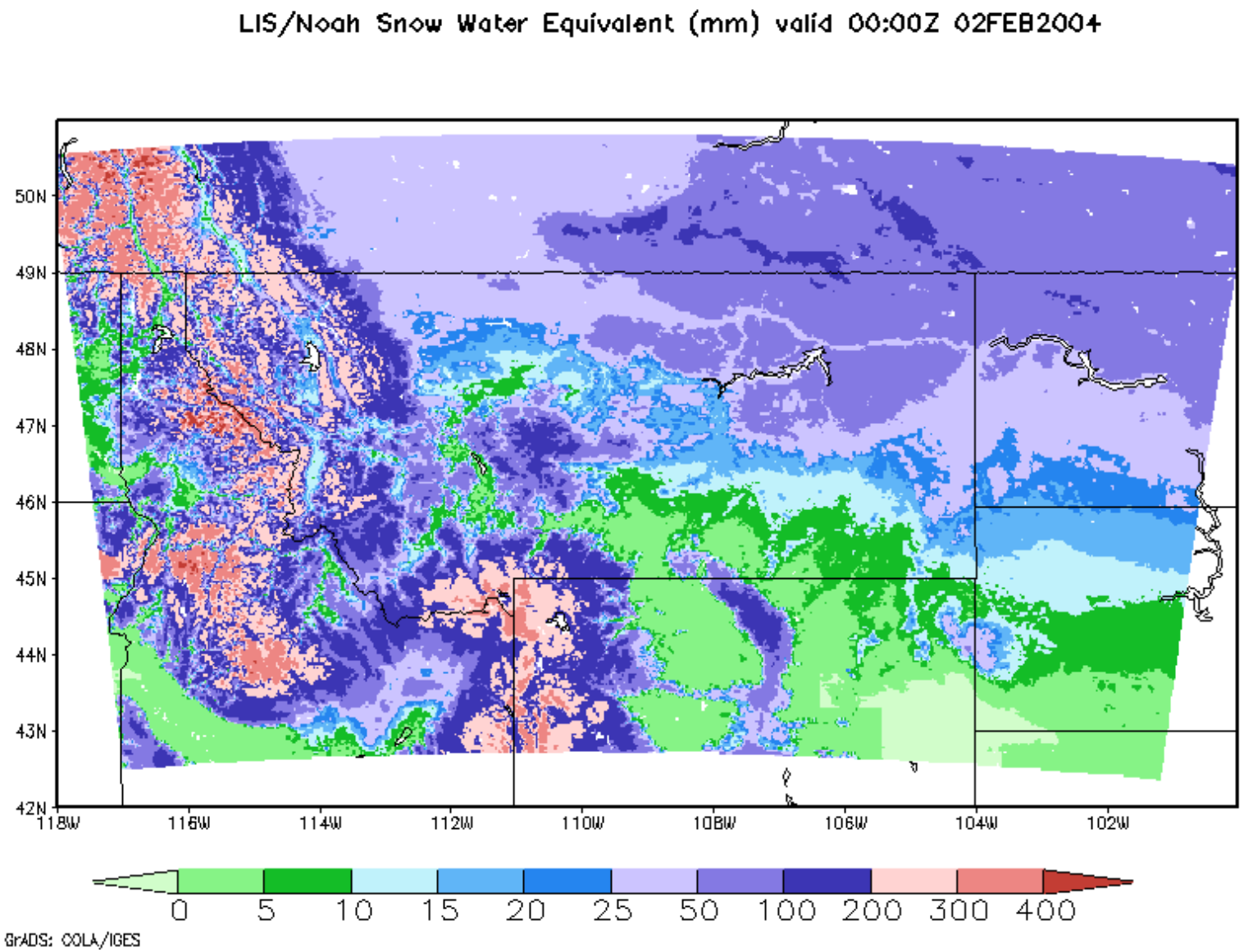
- LIS/Noah LSM run from 1 Jan 2002 to 1 Apr 2004
  - 1-km grid, 1300 x 900
  - Atmospheric forcing: 3-hourly GDAS analyses/forecasts
- Focus on Mar04 snowmelt
- Potential benefits of LIS
  - Supplement current MODIS false color with LIS SWE
  - Diagnostics for convective initiation
  - Monitor soil moisture trends
  - Initialize local high-res model
  - Hydrological applications



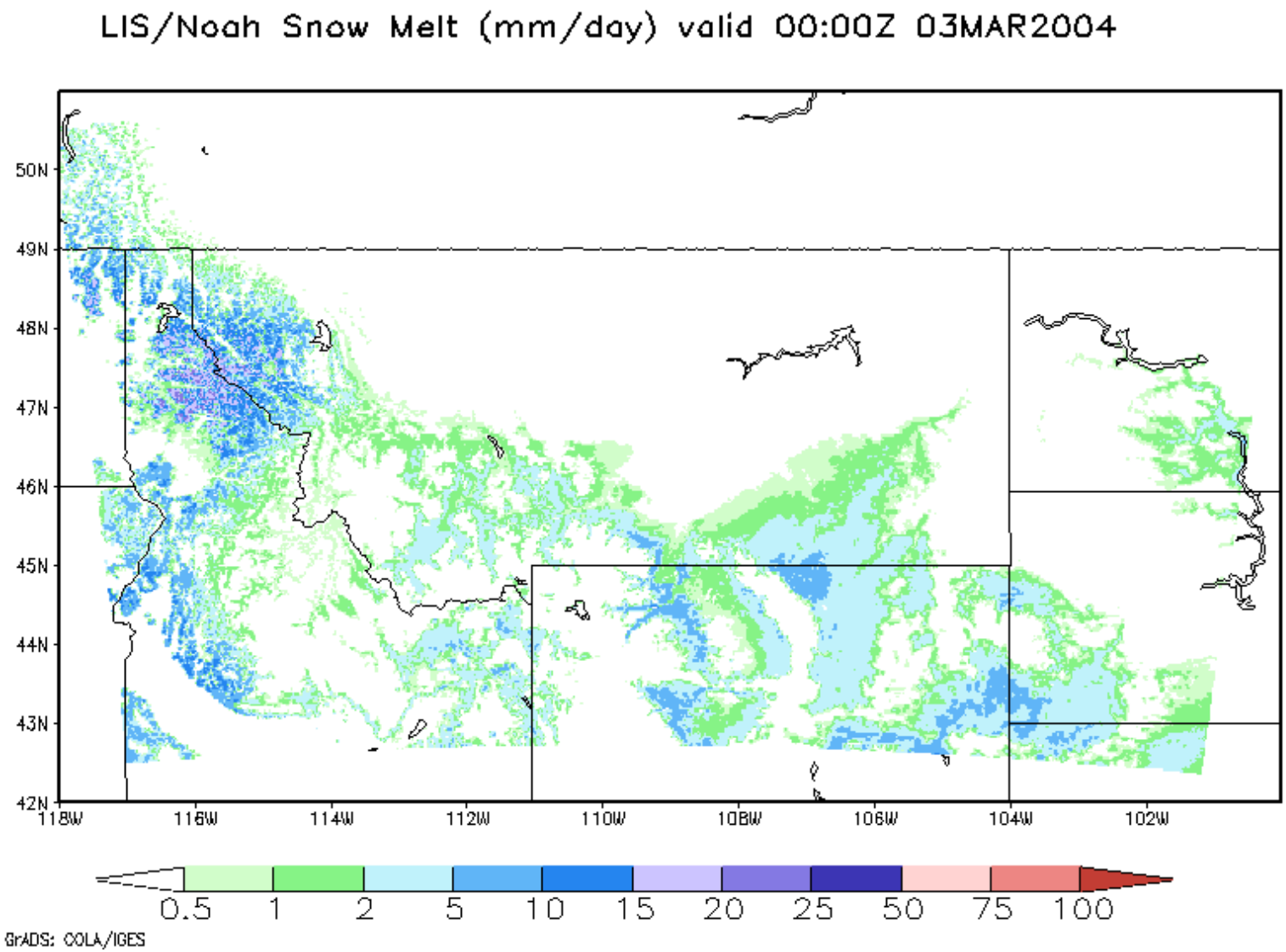


Sample 1-km LIS Output: Feb-Mar 2004 Snowmelt Event

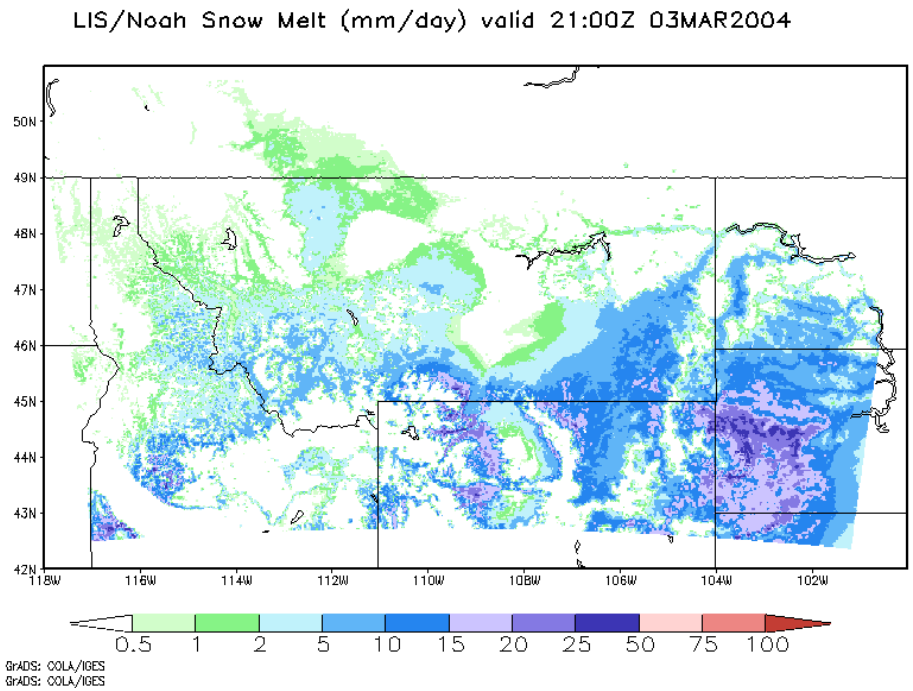
Once-Daily Output of SWE: Feb-Mar 2004

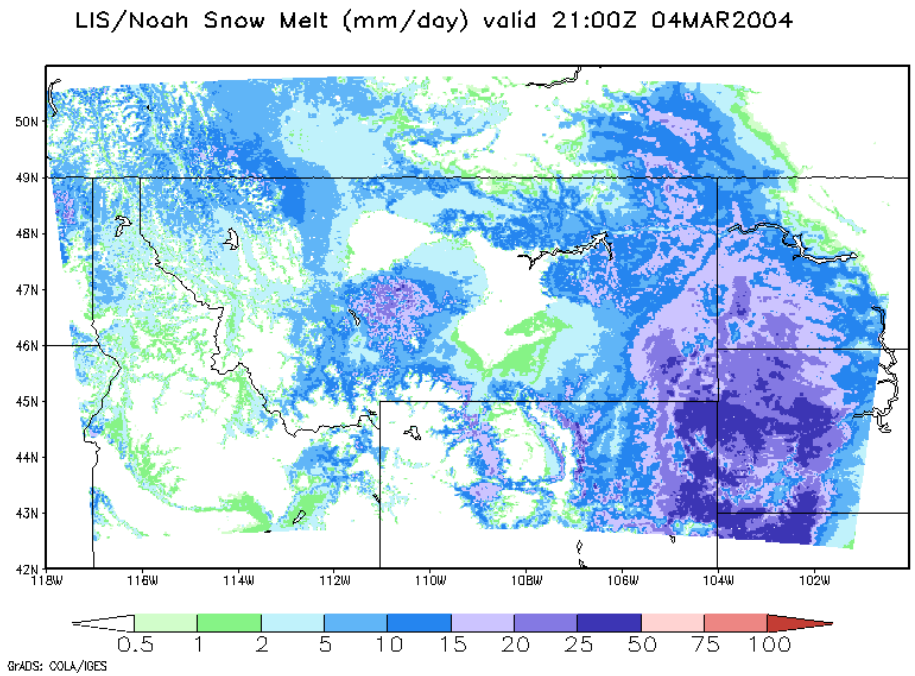


3-Hourly Output of Snow Melt: 3-11 Mar 2004

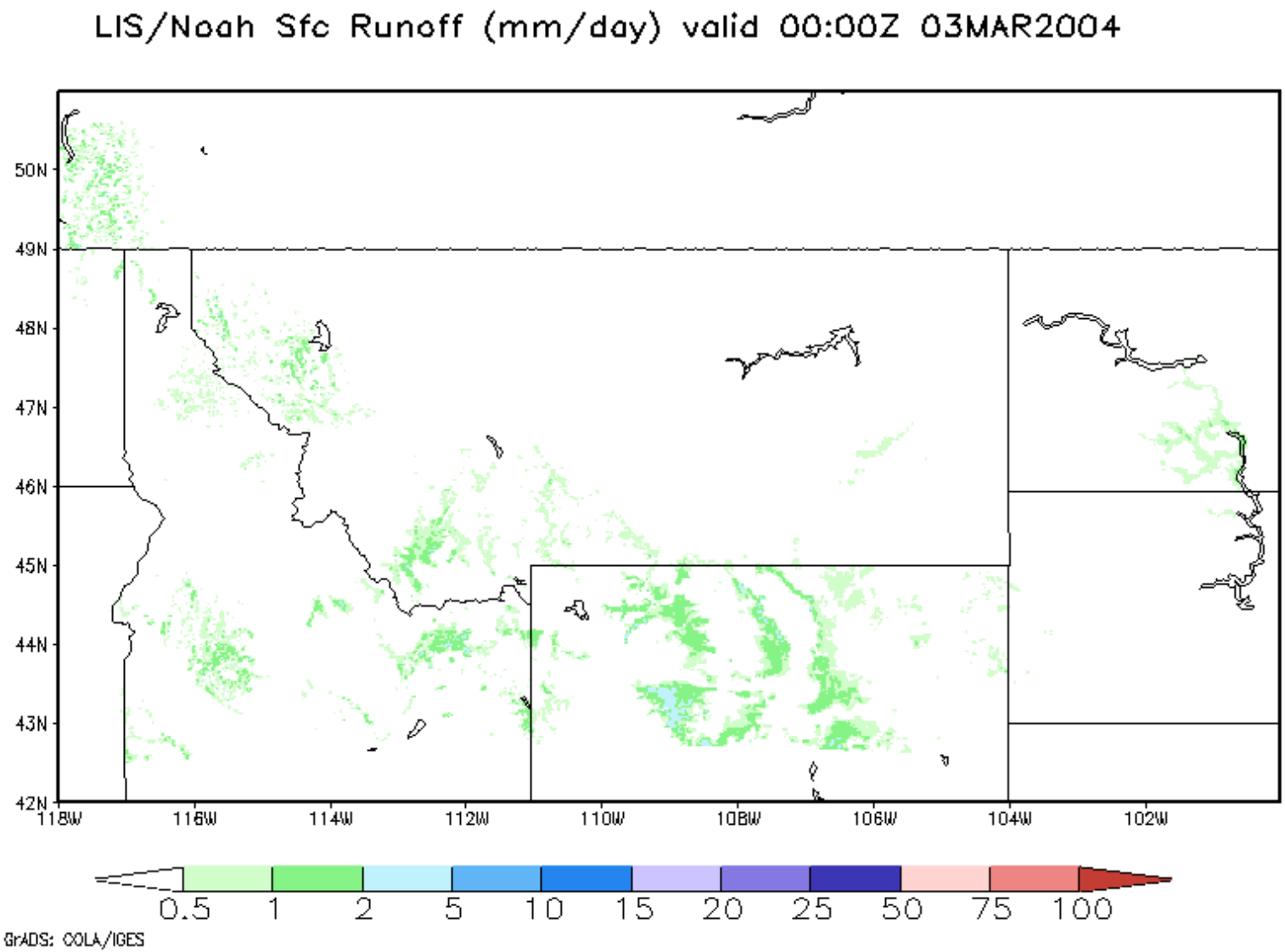


3-Hourly Output of Snow Melt: 3,4 Mar 2004 at 2100Z

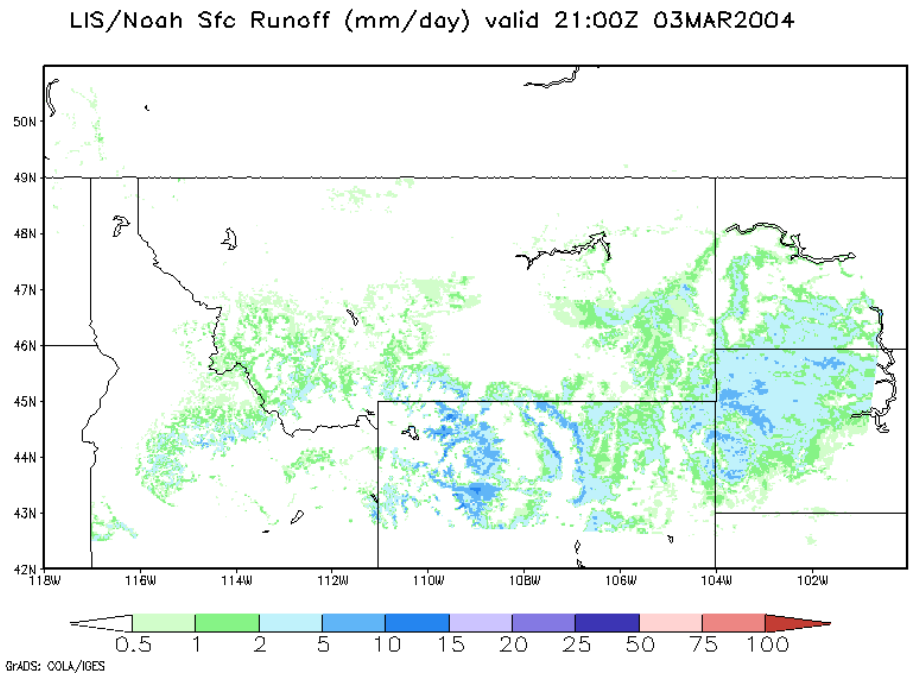


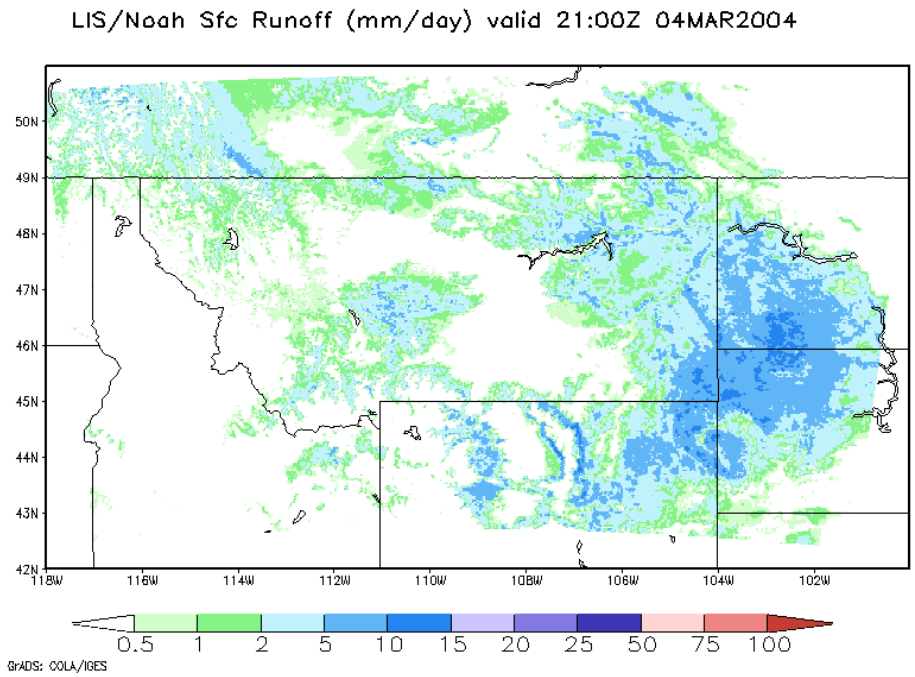


3-Hourly Output of Sfc Runoff: 3-11 Mar 2004



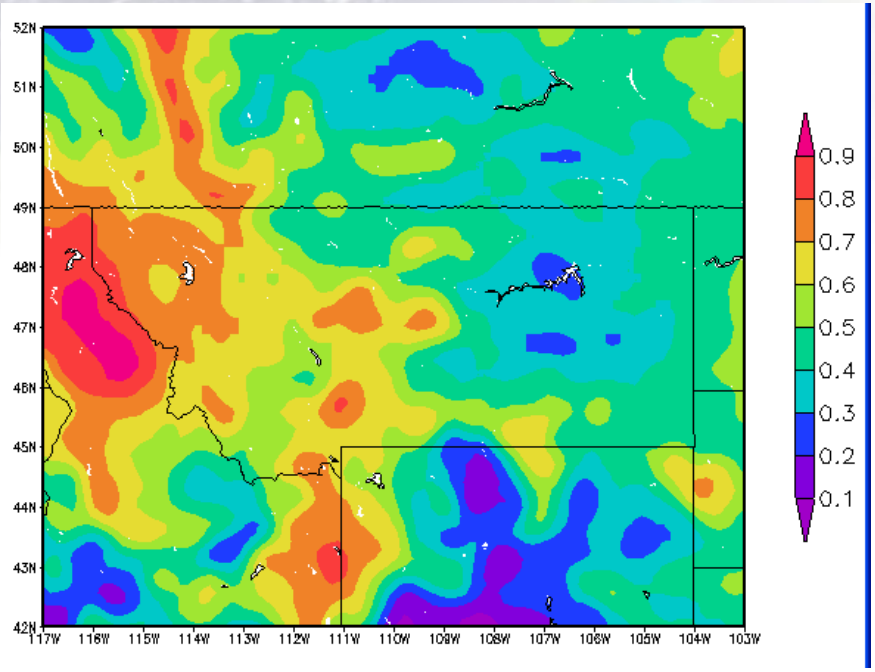
3-Hourly Output of Sfc Runoff: 3,4 Mar 2004 at 2100Z



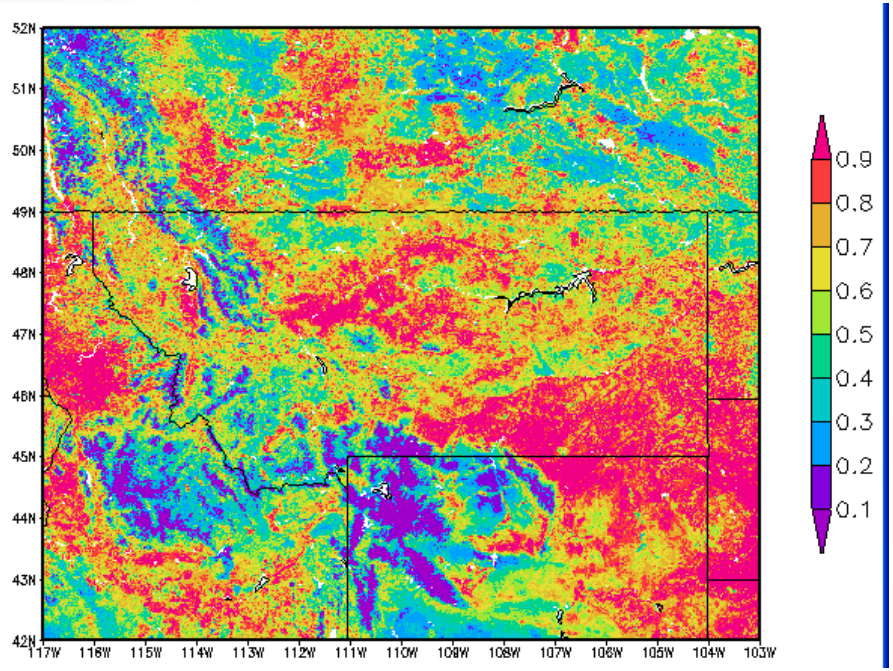


Ongoing SPoRT Efforts: Improved Vegetation in LIS

Current AVHRR June “Climo" GVF (1992-93 data)

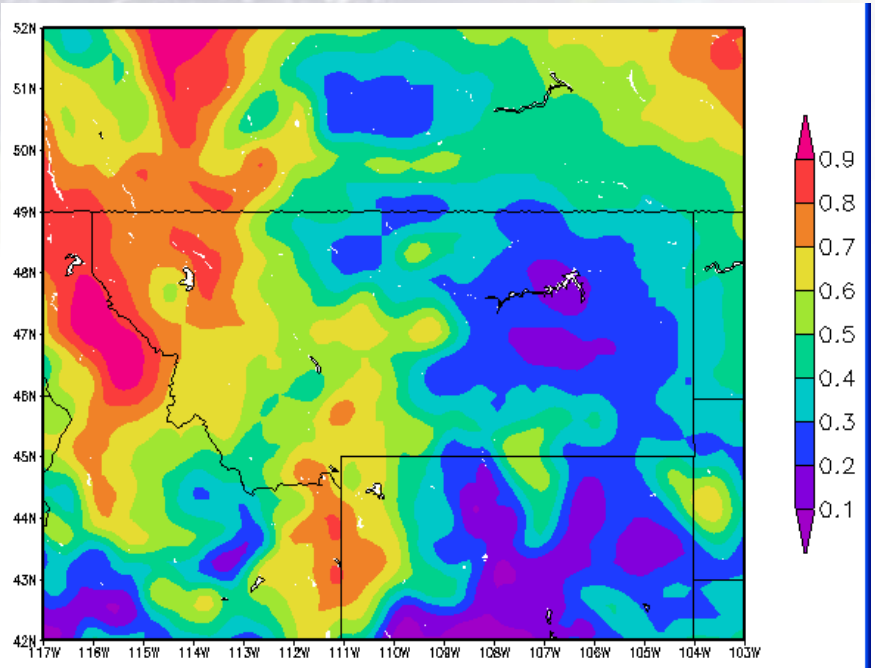


Prelim SPoRT/MODIS GVF (1 Jun 10)

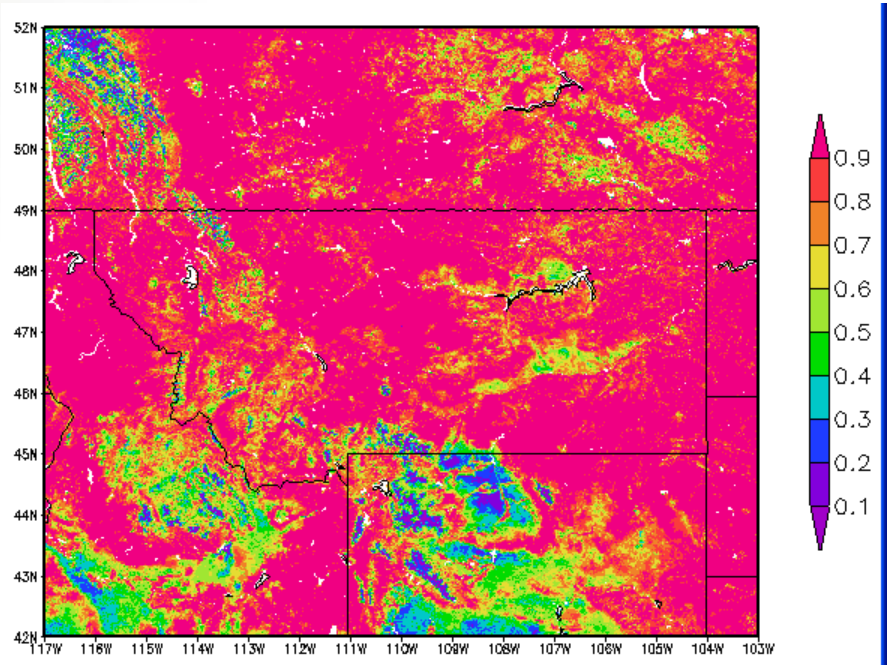


Ongoing SPoRT Efforts: Improved Vegetation in LIS

Current AVHRR July “Climo" GVF (1992-93 data)



Prelim SPoRT/MODIS GVF (1 Jul 10)



Introduction to FIRMS and HMS

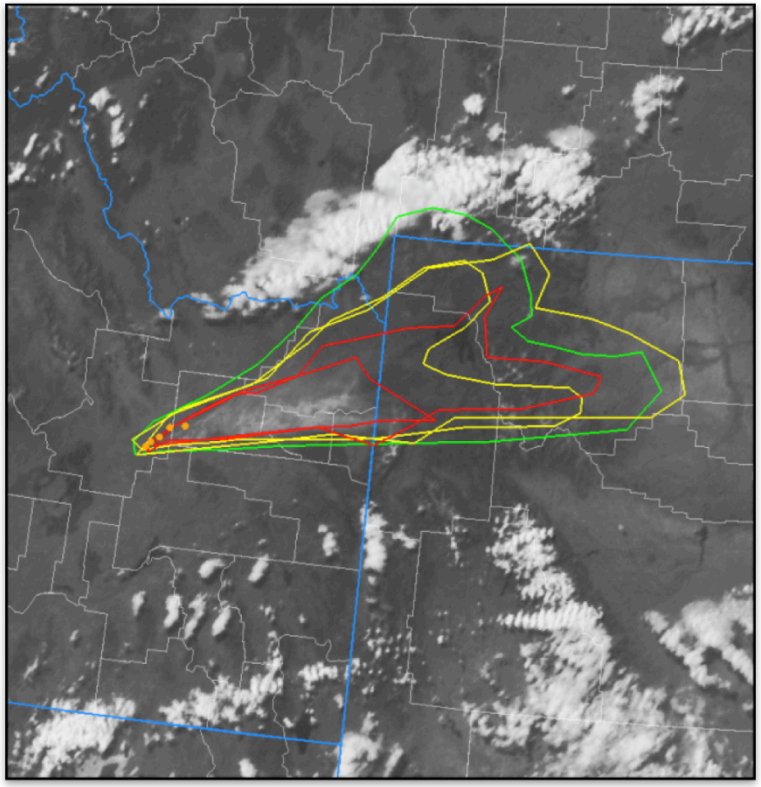
Purpose: *To improve a forecast problem (fire detection, flooding/slides, etc.) by making NASA data available with other data sets in user's native DSS.*

The Fire Information for Resource Management Systems (FIRMS) Fire/Hotspot Detections

- Funded by NASA to deliver near real-time fire/hotspot detections using the MODIS active fire locations processed by the MODIS Rapid Response System
- Processed using the standard MODIS Fire and Thermal Anomalies Product
- Represents the center of a 1-km pixel that is flagged by the algorithm as containing a fire within the pixel

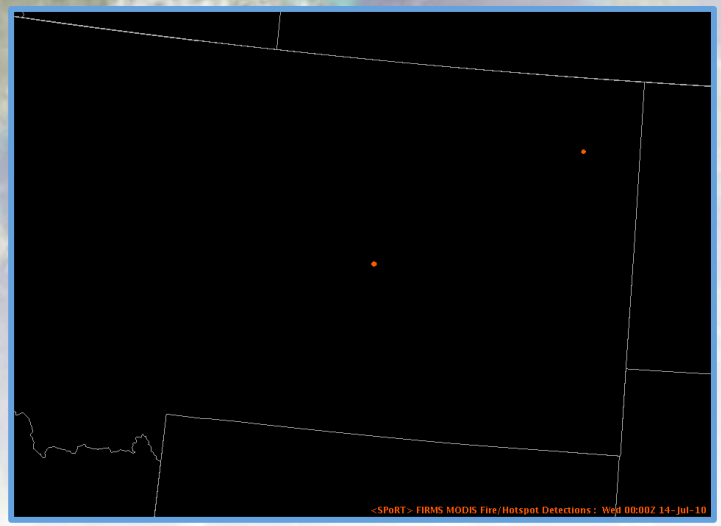
NESDIS Hazard Mapping System (HMS) Fire and Smoke Product

- Manually integrated from various automated fire detection algorithms w/ GOES, POES, MODIS, and DMSP images
- Quality-controlled locations of fires (points) and significant smoke plumes (polygons)



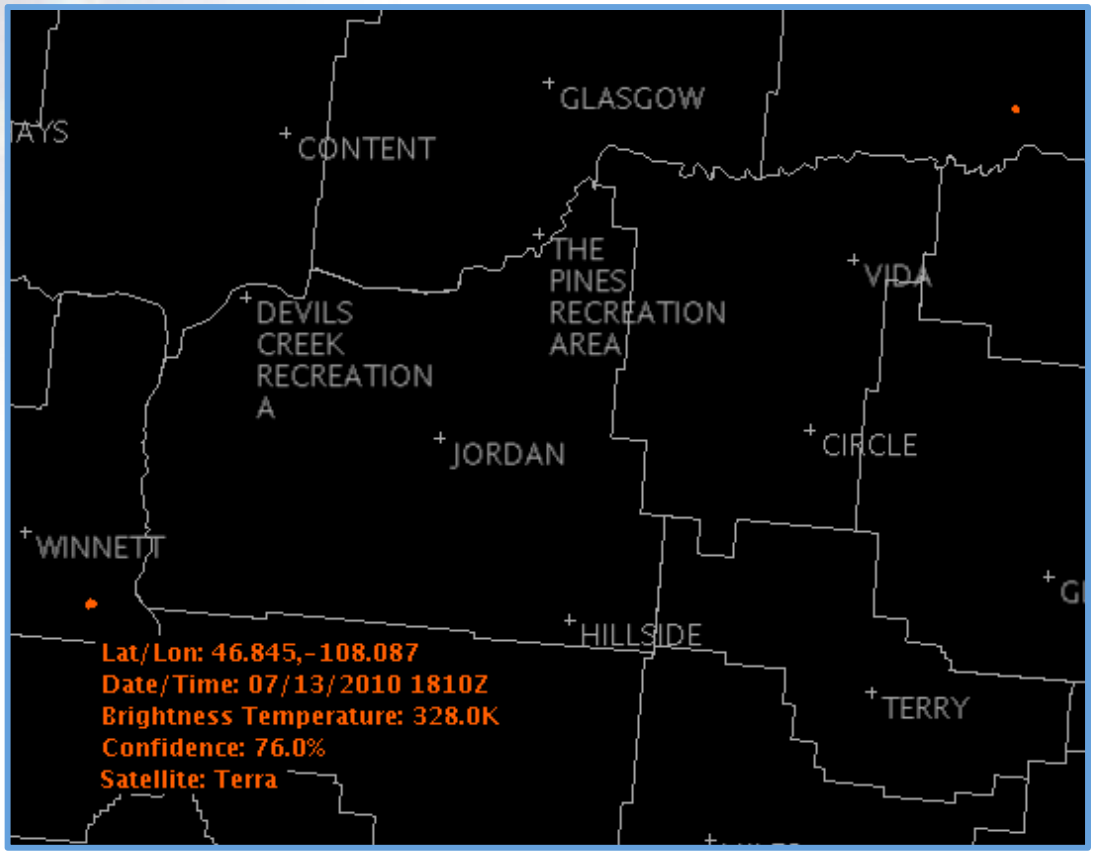
GOES Visible Image with 6-Hour Fire and Smoke Detections in Southeast Idaho

FIRMS MODIS Fire/Hotspot Detections



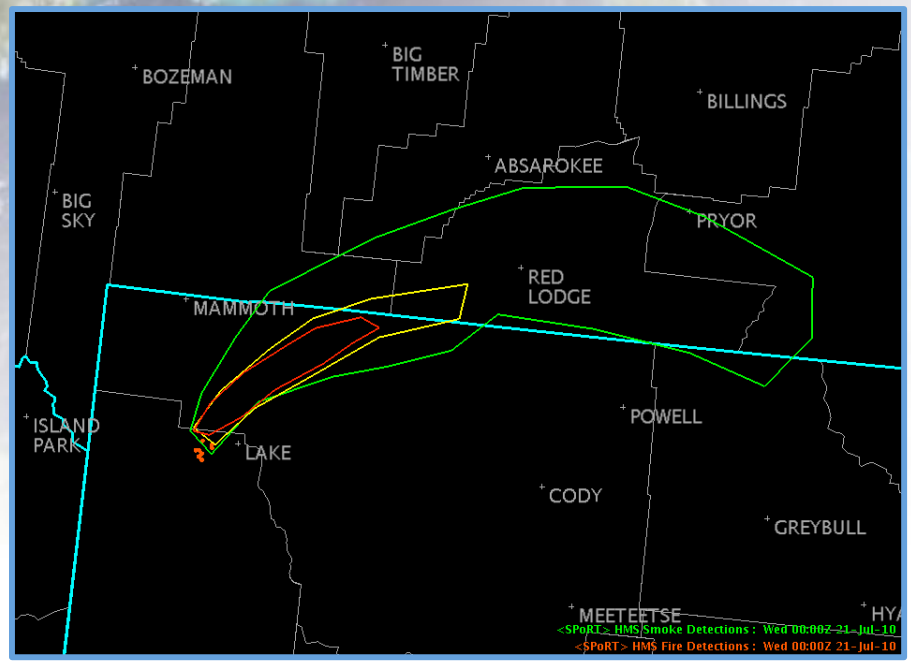
Zoomed In

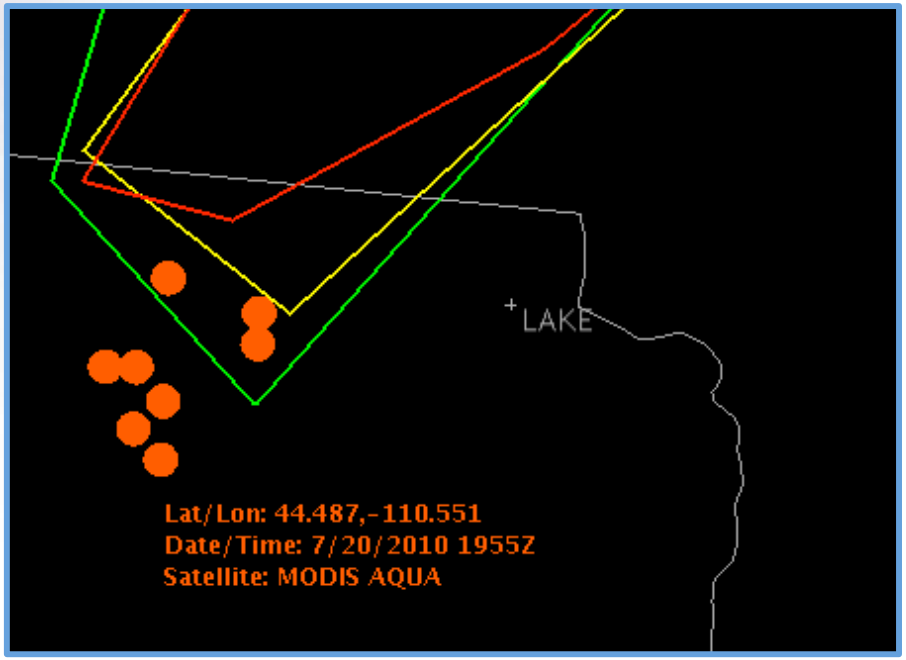
FIRMS detections contain additional information, including brightness temperature and confidence.



- Display of detections can be grouped into various temporal bins based on forecaster preferences or needs.
- Short term: 6-, 12-, or 24-hour for detection and monitoring
- Long term: 10-30 day product for burn scars
- Animation is also possible.

HMS Fire and Smoke Detections



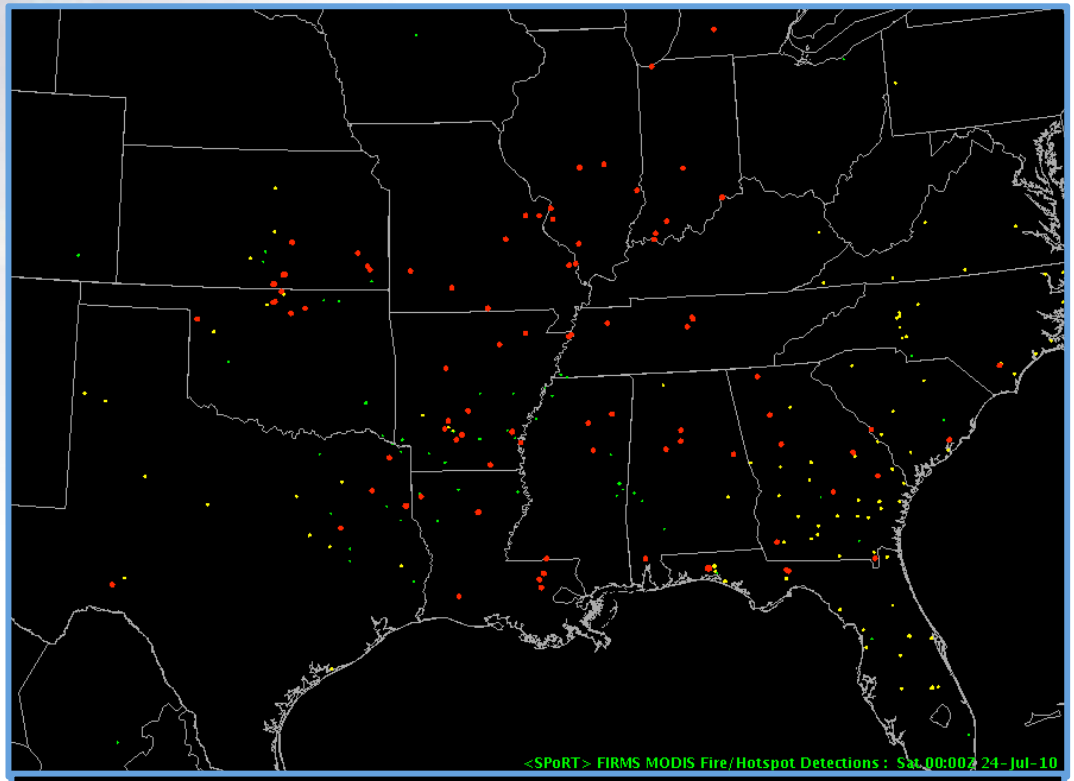


HMS Fire/Hotspot (red dots) and Smoke Detections (polygons; red="heavy" smoke, yellow="medium" smoke, and green="light" smoke) in Northwest Wyoming

- SPoRT has been collaborating with the NWS Huntsville WFO to develop plugins to display the detections in AWIPS II.
- The HMS Fire Detections are ingested in ASCII format and the Smoke Detections are ingested in KML format. Metadata is displayed by mousing over the detections.

Hotspot and Smoke Future Work

- Partner with NWS WFO(s) to determine best visualization methods (colors, time spans, animations, etc.)
- Testing and evaluation period; user feedback needed
- Make available to partners for ingestion into and display by AWIPS II



Red=0-24 hr Yellow=24-48 hr Green=48-72 hr

- FIRMS Data: http://maps.geog.umd.edu/firms/
- HMS Data: http://www.osdpd.noaa.gov/ml/land/hms.html