How AWIPS II is a Tool to Further R2O in the GOES-R Era

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Presentation Overview

Outline

- NRC Report on R2O
- CIMSS MODIS R2O History
- AWIPS II and Improved R2O
- GOES-R Proving Ground
- Data Fusion with AWG Products
- RGB/RGBA Image Combinations
- Potential AWIPS II Capabilities and Wish List
- Conclusions and Future Directions

Contributors

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- Paul Stanko, NWS Guam
- Philip Ardanuy, Frank Griffith, and programmers at Raytheon

NRC Report

In 2000, a report from the National Research Council (NRC) read—

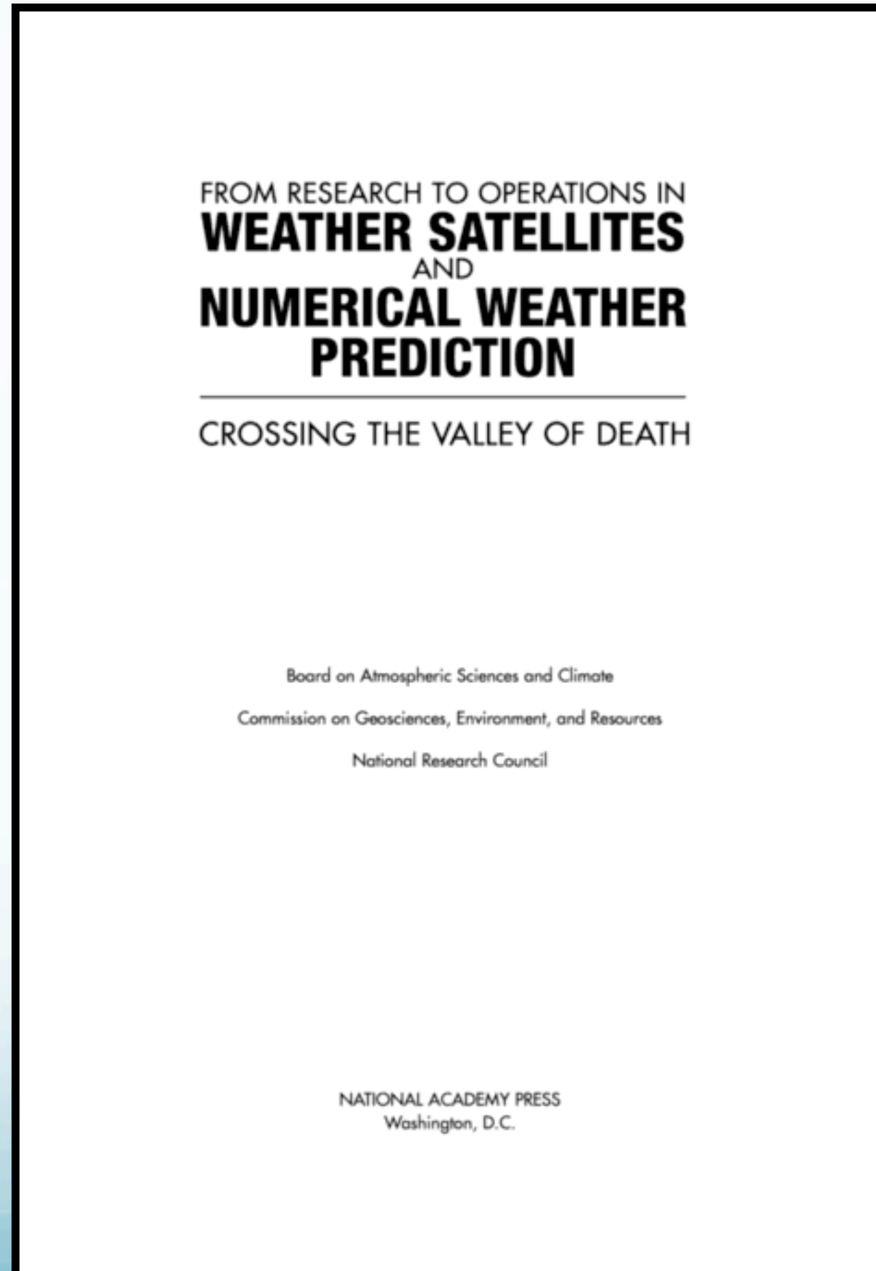
“Successful transitions from R&D to operational implementation always require:

(1) an understanding of the importance (and risks) of the transition,

(2) development and maintenance of appropriate transition plans,

(3) adequate resource provision, and

(4) a continuous feedback (in both directions) between R&D and operational activities.”



FROM RESEARCH TO OPERATIONS IN
WEATHER SATELLITES
AND
NUMERICAL WEATHER PREDICTION

CROSSING THE VALLEY OF DEATH

Board on Atmospheric Sciences and Climate

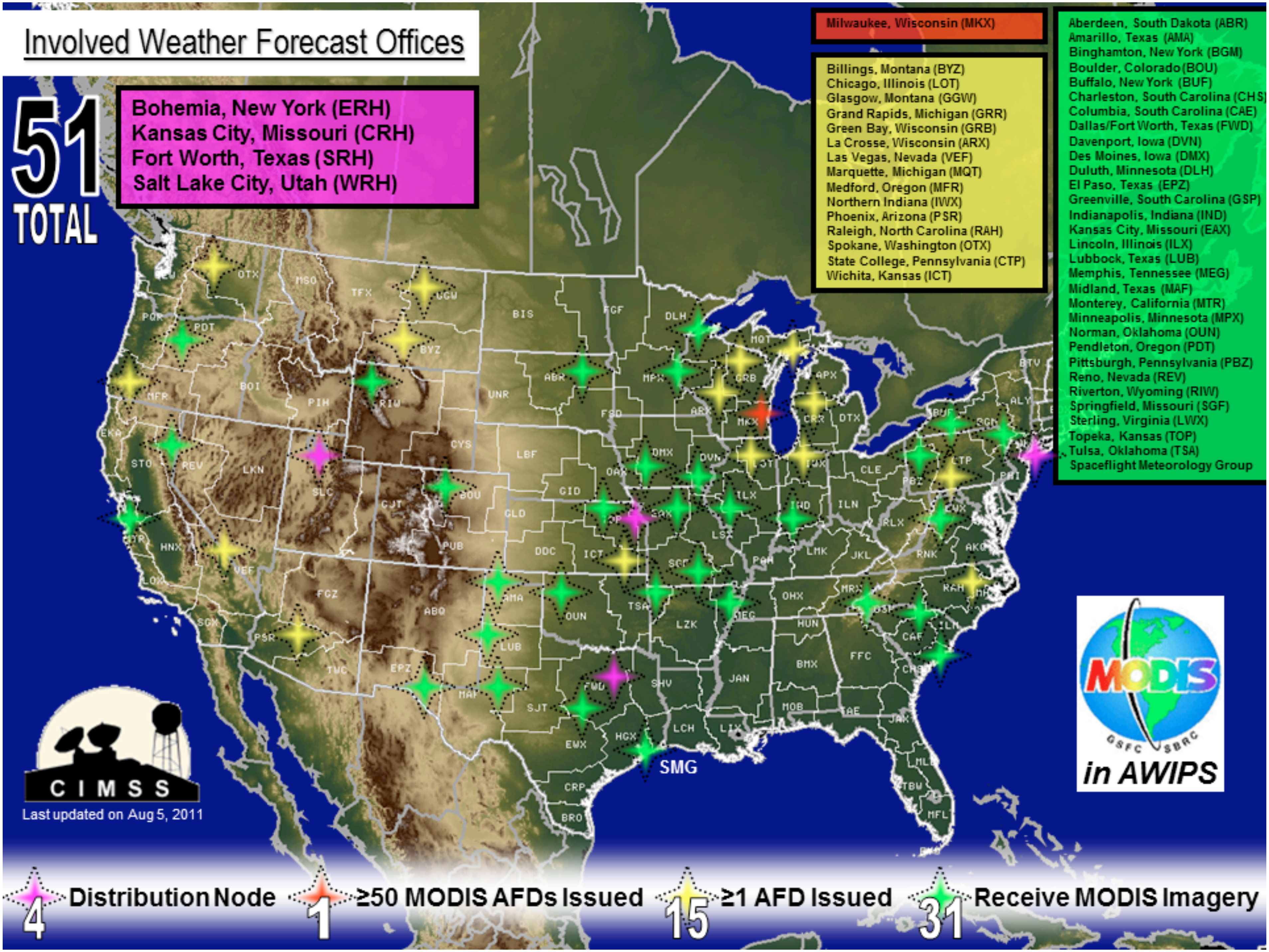
Commission on Geosciences, Environment, and Resources

National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

MODIS R2O History at CIMSS

- CIMSS grassroots effort to share the latest satellite imagery and products with the National Weather Service (NWS) began with a Research to Operations (R2O) project involving the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument to two NASA satellites.
- 2006 – CIMSS begins distribution of a subset of MODIS channels in netCDF3 to AWIPS I for use at the NWS forecast office in Milwaukee.
- 2008 – CIMSS successfully displays MODIS channels in early AWIPS II Task Orders.
- 2011 – CIMSS' direct distribution of MODIS imagery and products reaches 50 NWS offices, influencing more than 250 documented forecast decisions in about 5.5 years. Plans emerge to distribute VIIRS imagery.
- **2012 – CIMSS will transition MODIS distribution to data storage formats compliant with AWIPS II.**


Involved Weather Forecast Offices
51
TOTAL
Bohemia, New York (ERH)
Kansas City, Missouri (CRH)
Fort Worth, Texas (SRH)
Salt Lake City, Utah (WRH)
Milwaukee, Wisconsin (MKX)
Billings, Montana (BYZ)
Chicago, Illinois (LOT)
Glasgow, Montana (GGW)
Grand Rapids, Michigan (GRR)
Green Bay, Wisconsin (GRB)
La Crosse, Wisconsin (ARX)
Las Vegas, Nevada (VEF)
Marquette, Michigan (MQT)
Medford, Oregon (MFR)
Northern Indiana (IWX)
Phoenix, Arizona (PSR)
Raleigh, North Carolina (RAH)
Spokane, Washington (OTX)
State College, Pennsylvania (CTP)
Wichita, Kansas (ICT)
Aberdeen, South Dakota (ABR)
Amarillo, Texas (AMA)
Binghamton, New York (BGM)
Boulder, Colorado (BOU)
Buffalo, New York (BUF)
Charleston, South Carolina (CHS)
Columbia, South Carolina (CAE)
Dallas/Fort Worth, Texas (FWD)
Davenport, Iowa (DVN)
Des Moines, Iowa (DMX)
Duluth, Minnesota (DLH)
El Paso, Texas (EPZ)
Greenville, South Carolina (GSP)
Indianapolis, Indiana (IND)
Kansas City, Missouri (EAX)
Lincoln, Illinois (ILX)
Lubbock, Texas (LUB)
Memphis, Tennessee (MEG)
Midland, Texas (MAF)
Monterey, California (MTR)
Minneapolis, Minnesota (MPX)
Norman, Oklahoma (OUN)
Pendleton, Oregon (PDT)
Pittsburgh, Pennsylvania (PBZ)
Reno, Nevada (REV)
Riverton, Wyoming (RIW)
Springfield, Missouri (SGF)
Sterling, Virginia (LWX)
Topeka, Kansas (TOP)
Tulsa, Oklahoma (TSA)
Spaceflight Meteorology Group
SMG
CIMSS
Last updated on Aug 5, 2011
MODIS
GSFC SBRC
in AWIPS
Distribution Node
4
≥50 MODIS AFDs Issued
1
≥1 AFD Issued
15
Receive MODIS Imagery
31

AWIPS "II" (2012+)

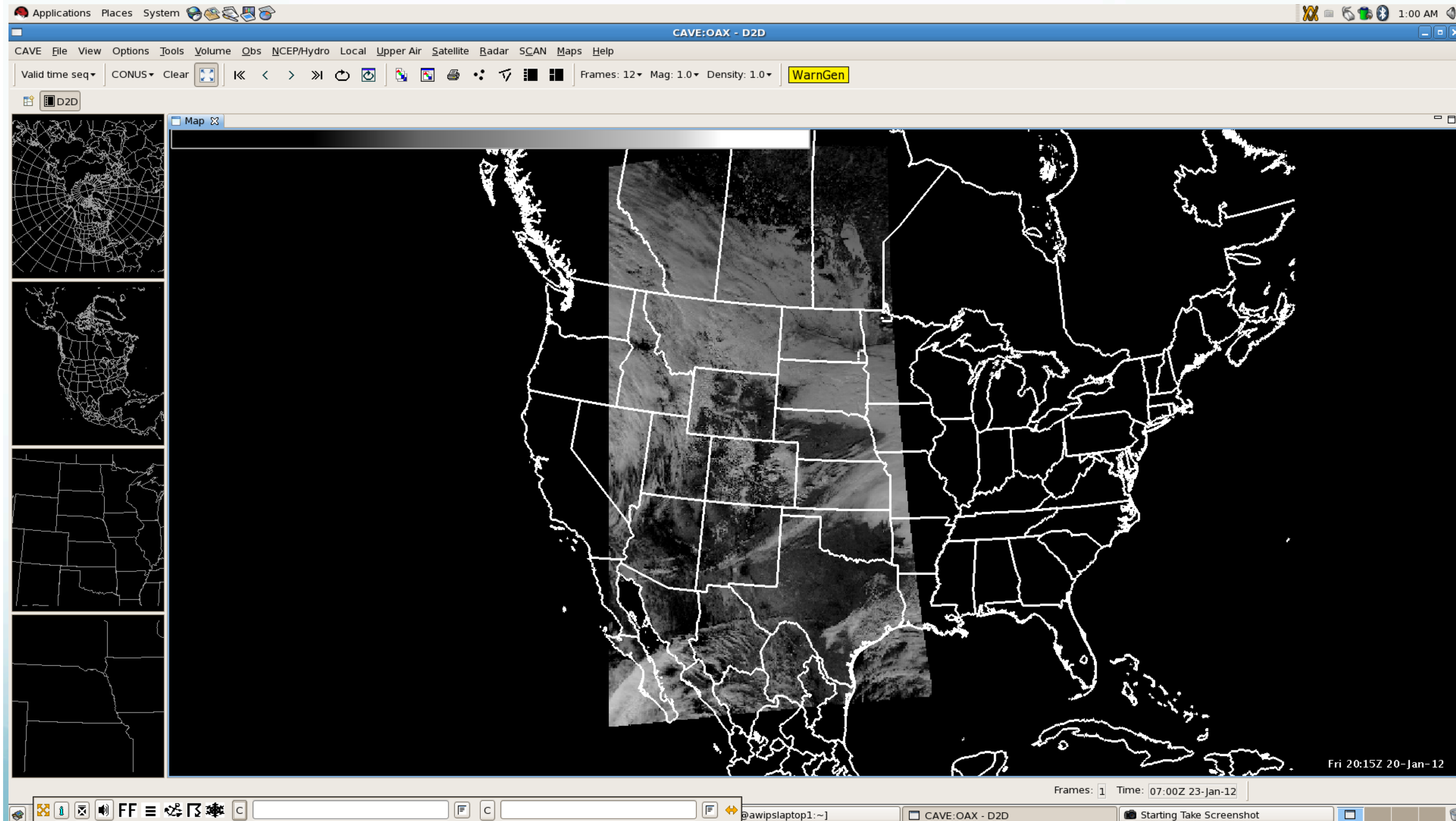
The Advanced Weather Interactive Processing System

- Service-oriented, client-server architecture, plug-in enabled
- Two primary components which can standalone
  - Environmental Data EXchange (EDEX); HDF5 data store
  - Common AWIPS Visualization Environment (CAVE)
- Code arranged in object-oriented Java design
- Scalable to multiple platforms, computing systems
- Some C and FORTRAN used to optimized performance
- Configuration through eXtensible Markup Language (XML) and Python with numpy
- Employs shader language for on-GPU calculations
- Raytheon-developed code is non-proprietary with unlimited Government purpose rights and eventually will be available to the community through Unidata

How AWIPS II will Improve R2O

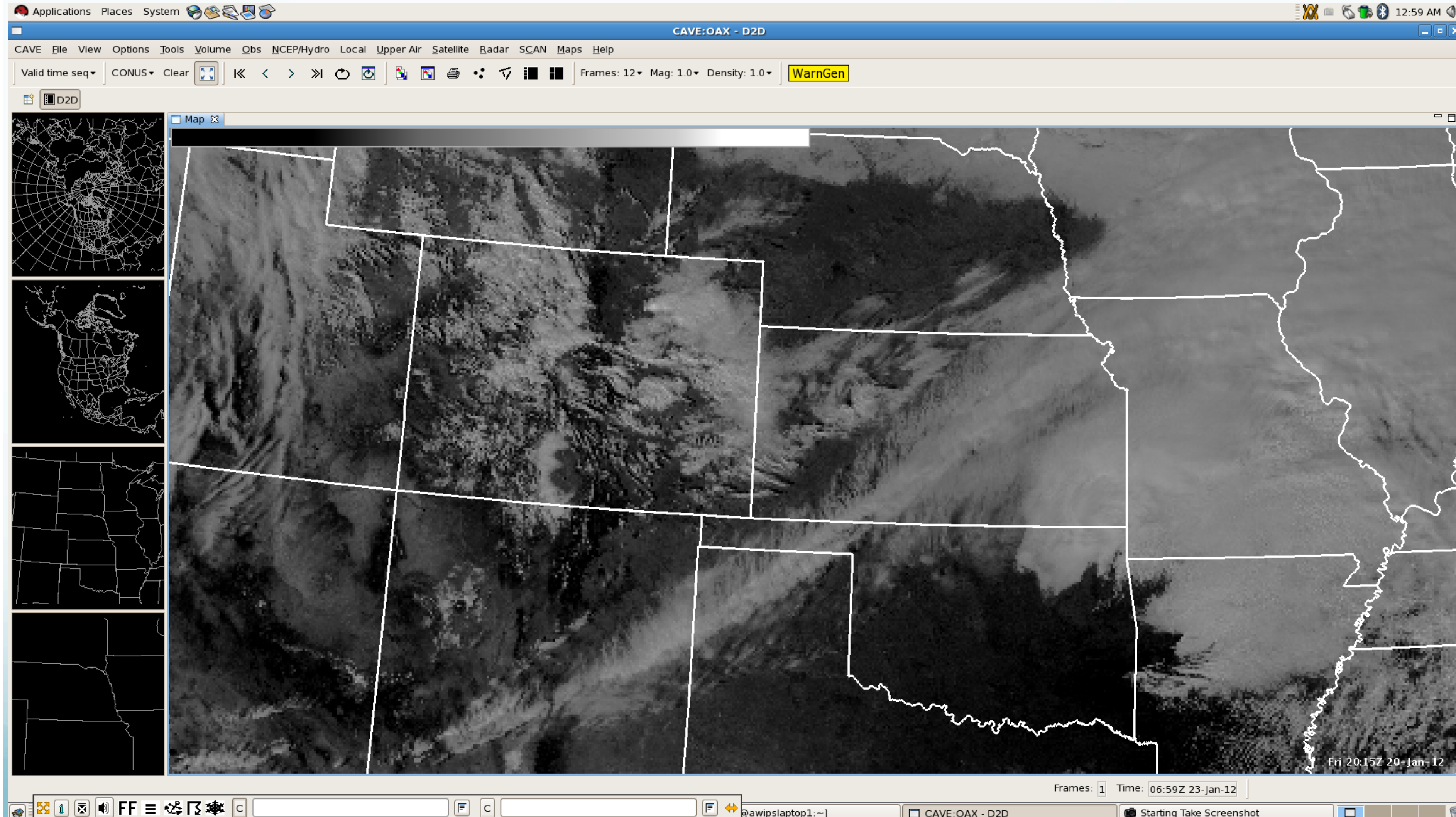
- Compared to geostationary satellites, polar satellites provide observations on greater spatial and spectral scales, while geostationary satellites provide more expansive coverage over a short time interval, ideal for operational meteorologists in the mid-latitudes and tropics
- Legacy AWIPS did not allow multi-layer image combinations
- SPoRT initially built a combined MODIS and GOES product *prior* to transmitting it to legacy AWIPS
- **By supporting dynamic image data array manipulations, AWIPS II:**
  - **allows for more timely creation of this product,**
  - **promotes a single, fused source for satellite information, and**
  - **decreases bandwidth usage while increasing value of imagery to the forecasters.**

Image Layering in AWIPS II



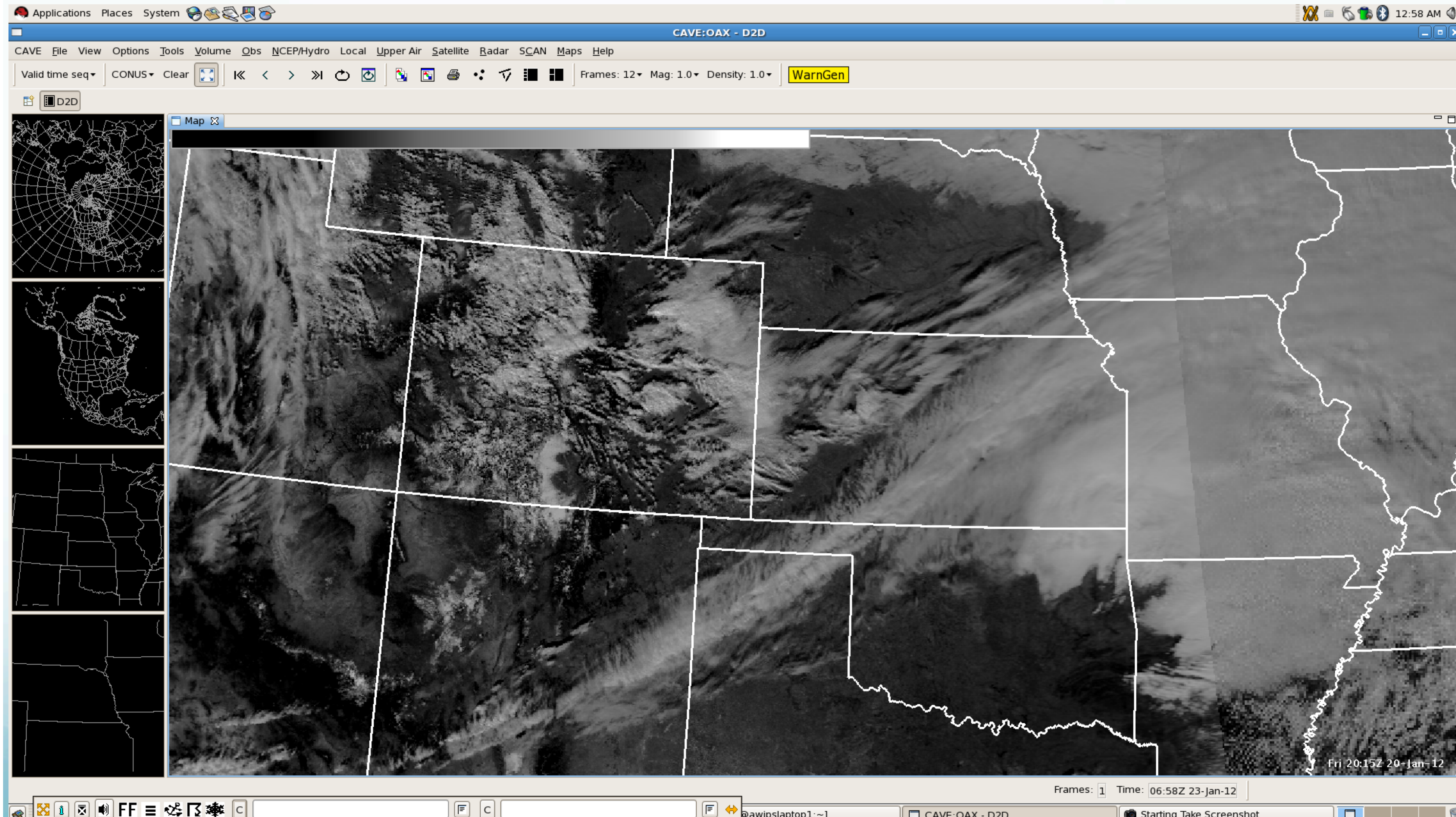
Coverage of 1 km MODIS visible imagery swath, 20:15 UTC 20 January 2012

Image Layering in AWIPS II



GOES-13 (East) imagery only, 20:15 UTC 20 January 2012

Image Layering in AWIPS II



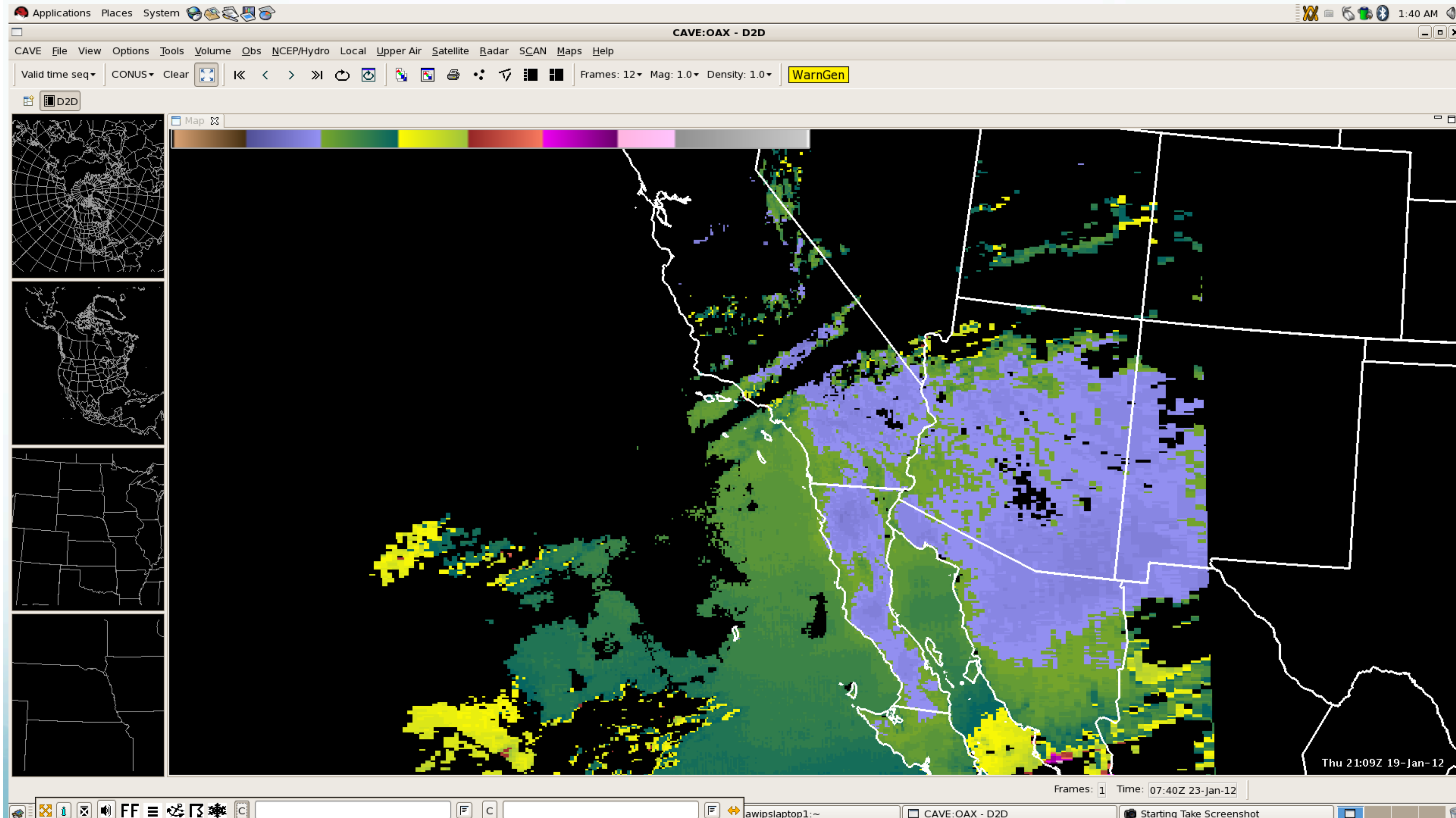
Combination of MODIS and GOES visible imagery, 20:15 UTC 20 January 2012

AWIPS II Strategy at CIMSS

- Leverage existing AWIPS II plug-ins (GRIB2, McIDAS AREA, GINI), update configuration tables, and reformat current AWIPS satellite imagery and products from CIMSS to a plug-in-compliant format

- Improve and guide development of existing and new AWIPS II plug-ins (netCDF3/4)
  - Expand data array structure
    - Currently byte values
  - Add advanced map projections, additional geospatial support
    - Pursuing strategies to add satellite perspectives (polar and geostationary)
    - Currently limited to Mercator, Lambert Conformal, and Polar Stereographic

MODIS TPW in AWIPS II

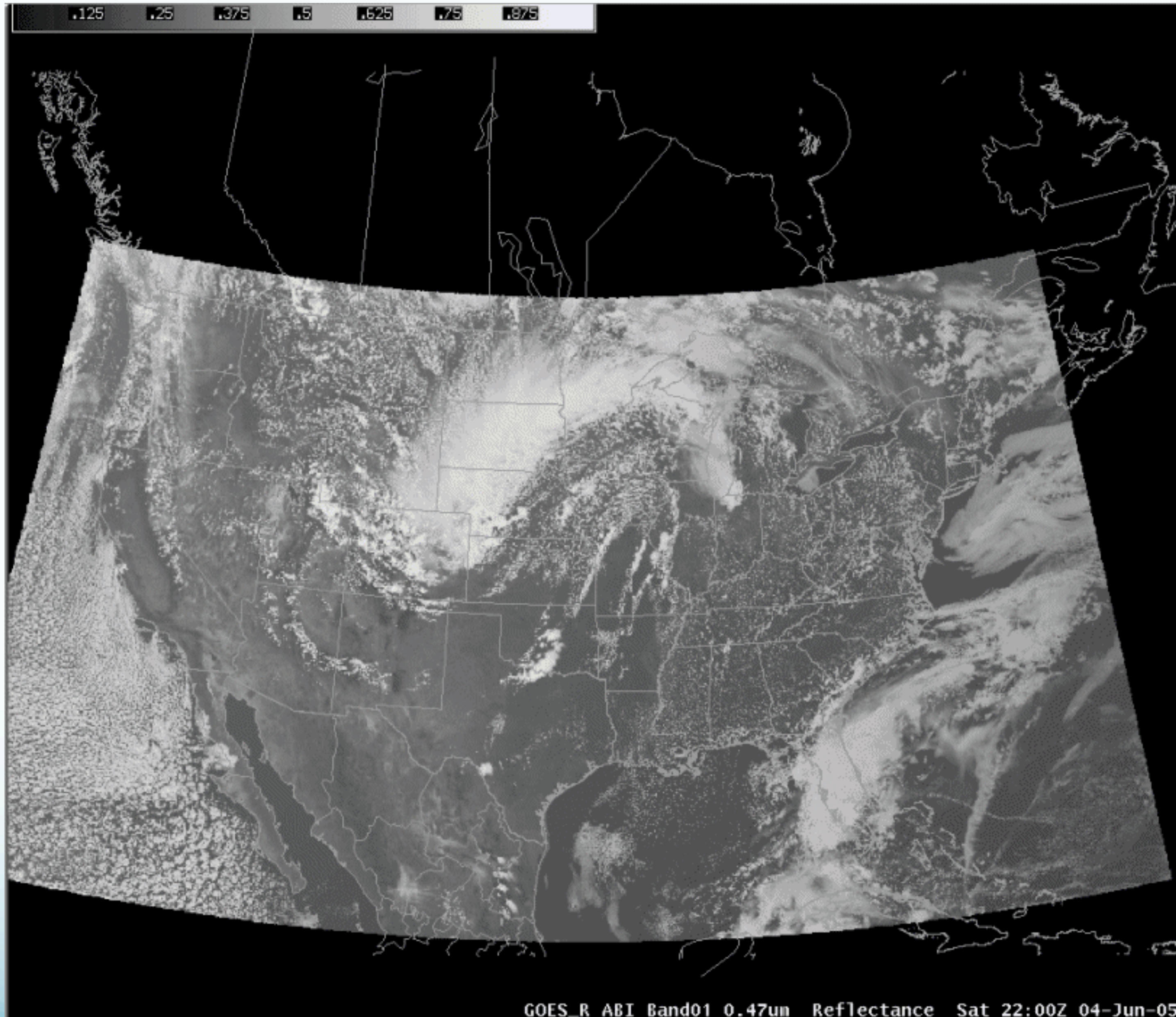


CIMSS legacy Total Precipitable Water (TPW) product, 21:09 UTC 19 January 2012

GOES-R/S Series (2017 to 2028)
The Geostationary Operational Environmental Satellite

- Launching in 2015, GOES-R is expected to be GOES-West
- Two meteorological instruments
- The Advanced Baseline Imager (ABI) will provide
  - 5x more frequent scans (5 minute for full disk, 30 second refresh for single mesoscale sector),
  - 4x improved temporal resolution (2 km at sub-satellite point, except 0.5 km visible), and
  - 3x more spectral channels (16 total, including 4 in the near-IR and 10 in the IR)

  than currently on GOES-13/14/15 (N/O/P)
- An optical sensor on the Geostationary Lightning Mapper (GLM) will provide continuous lightning flash rates
- No Sounder



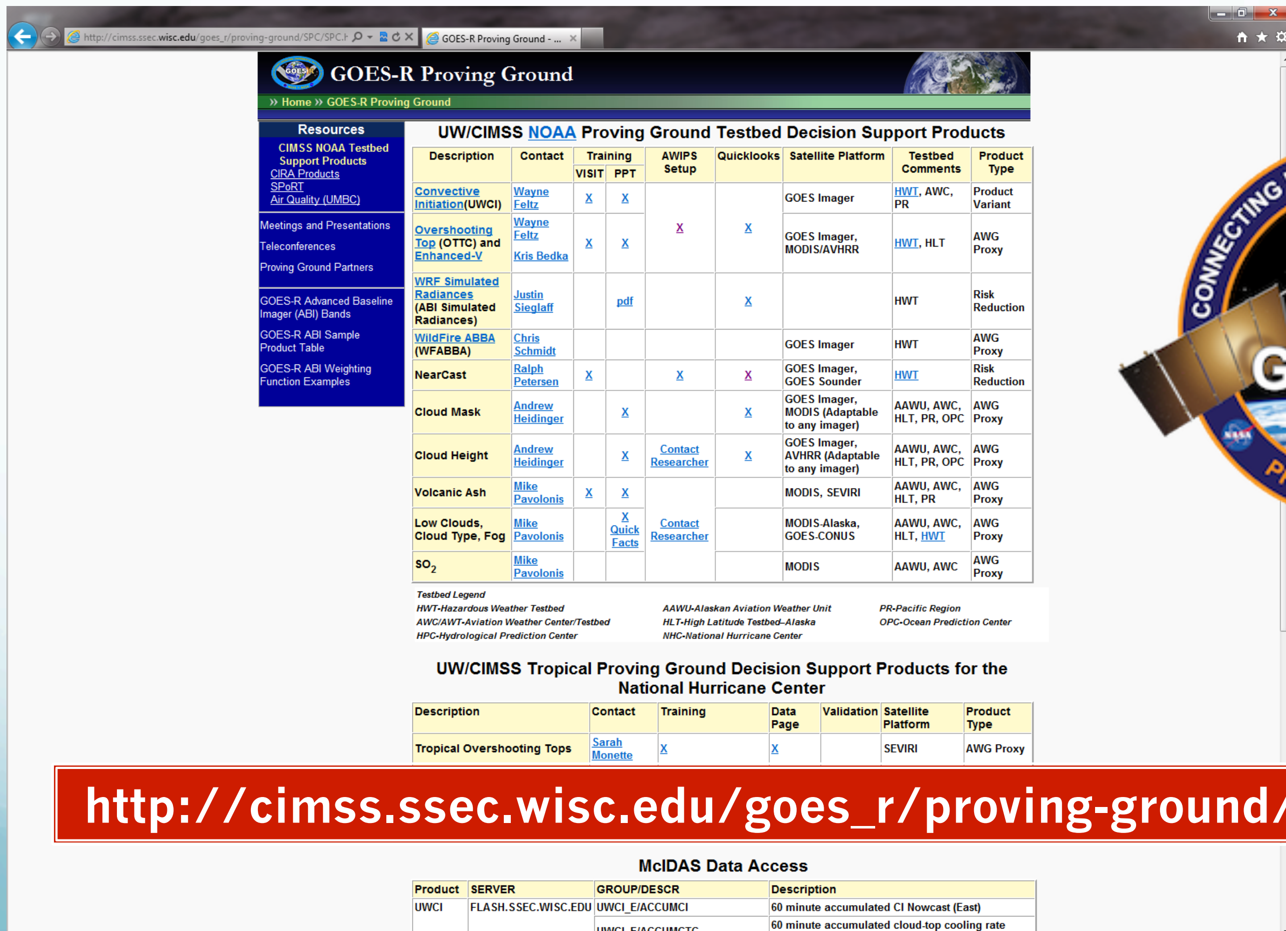
Images from Weather Event Simulator (WES) case available to NWS sites

GOES-R Proving Ground

- A proving ground is designed to showcase future capabilities and identify possible gaps as a forward-thinking exercise to prepare the end user for upcoming science and technology and assure that the capabilities meet user requirements.
- The GOES-R Proving Ground is a collective effort between many NOAA and NOAA-supported agencies and universities.
- The primary customer is the National Weather Service. To assure widespread evaluation and readiness across the NWS, the GOES-R Proving Ground is leveraging existing testbeds at the National Centers, and starting new ones where they do not exist, as well as hiring "satellite champions".
- NWS Weather Forecast Offices can participate in the Proving Ground because all imagery and products are formatted for AWIPS, N-AWIPS, and eventually AWIPS II.

GOES-R Proving Ground

- CIMSS supports over 70 NWS sites across the country.



GOES-R Proving Ground

» Home » GOES-R Proving Ground

Resources

CIMSS NOAA Testbed Support Products
CIRA Products
SPoRT
Air Quality (UMBC)

Meetings and Presentations
Teleconferences
Proving Ground Partners

GOES-R Advanced Baseline Imager (ABI) Bands
GOES-R ABI Sample Product Table
GOES-R ABI Weighting Function Examples

UW/CIMSS NOAA Proving Ground Testbed Decision Support Products

Description	Contact	Training		AWIPS Setup	Quicklooks	Satellite Platform	Testbed Comments	Product Type
		VISIT	PPT					
Convective Initiation(UWCI)	Wayne Feltz	X	X	X	X	GOES Imager	HWT, AWC, PR	Product Variant
Overshooting Top (OTTC) and Enhanced-V	Wayne Feltz Kris Bedka	X	X			GOES Imager, MODIS/AVHRR	HWT, HLT	AWG Proxy
WRF Simulated Radiances (ABI Simulated Radiances)	Justin Sieglaff		pdf		X		HWT	Risk Reduction
WildFire ABBA (WFABBA)	Chris Schmidt					GOES Imager	HWT	AWG Proxy
NearCast	Ralph Petersen	X		X	X	GOES Imager, GOES Sounder	HWT	Risk Reduction
Cloud Mask	Andrew Heidinger		X		X	GOES Imager, MODIS (Adaptable to any imager)	AAWU, AWC, HLT, PR, OPC	AWG Proxy
Cloud Height	Andrew Heidinger		X	Contact Researcher	X	GOES Imager, AVHRR (Adaptable to any imager)	AAWU, AWC, HLT, PR, OPC	AWG Proxy
Volcanic Ash	Mike Pavolonis	X	X	Contact Researcher		MODIS, SEVIRI	AAWU, AWC, HLT, PR	AWG Proxy
Low Clouds, Cloud Type, Fog	Mike Pavolonis		X Quick Facts			MODIS-Alaska, GOES-CONUS	AAWU, AWC, HLT, HWT	AWG Proxy
SO_2	Mike Pavolonis					MODIS	AAWU, AWC	AWG Proxy

Testbed Legend
HWT-Hazardous Weather Testbed
AWC/AWT-Aviation Weather Center/Testbed
HPC-Hydrological Prediction Center
AAWU-Alaskan Aviation Weather Unit
HLT-High Latitude Testbed–Alaska
NHC-National Hurricane Center
PR-Pacific Region
OPC-Ocean Prediction Center

UW/CIMSS Tropical Proving Ground Decision Support Products for the National Hurricane Center

Description	Contact	Training	Data Page	Validation	Satellite Platform	Product Type
Tropical Overshooting Tops	Sarah Monette	X	X		SEVIRI	AWG Proxy

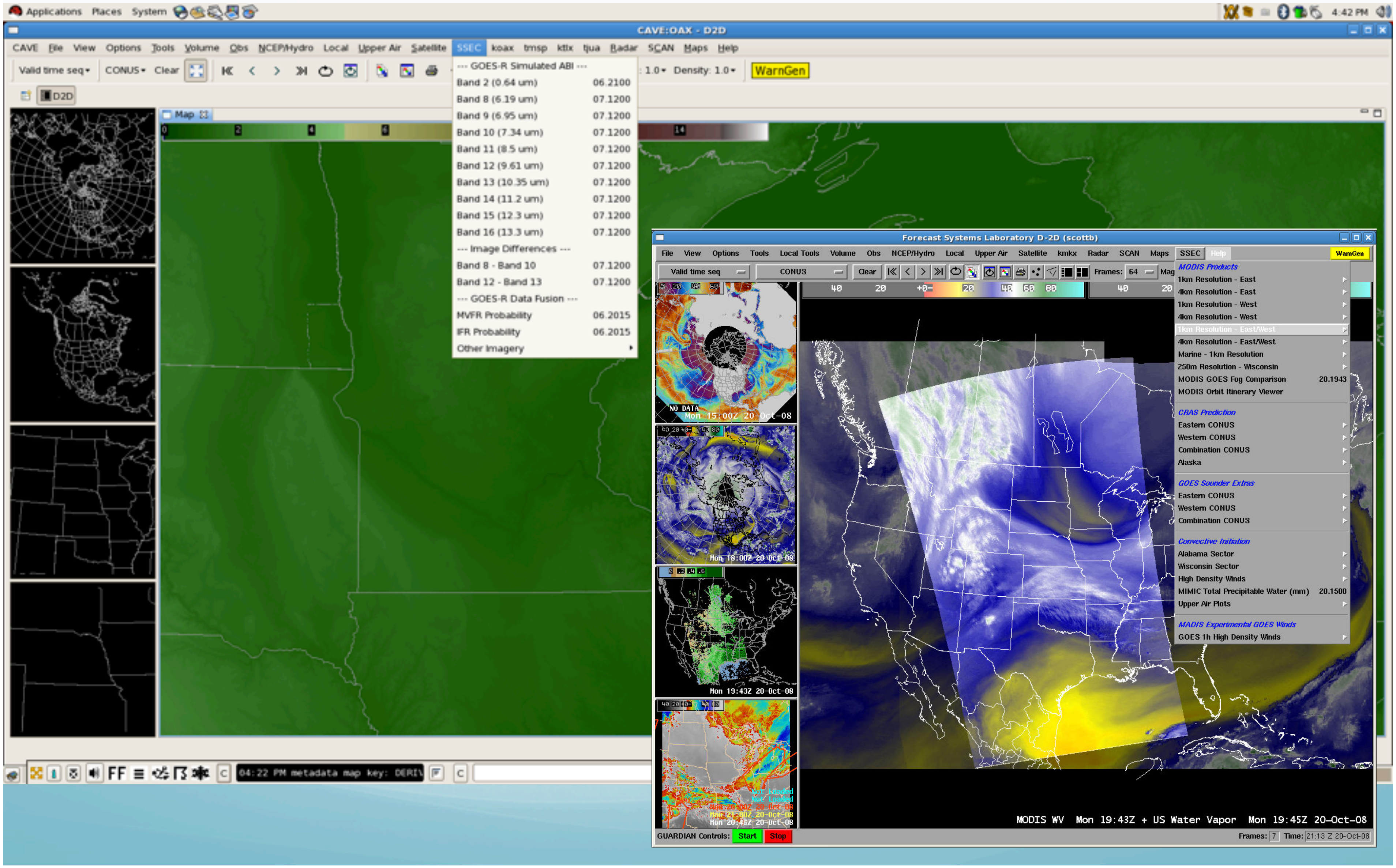
McIDAS Data Access

Product	SERVER	GROUP/DESCR	Description
UWCI	FLASH.SSEC.WISC.EDU	UWCI_E/ACCUMCI	60 minute accumulated CI Nowcast (East)
		UWCI_E/ACCUMCTC	60 minute accumulated cloud-top cooling rate (East)

http://cimss.ssec.wisc.edu/goes_r/proving-ground/SPC/SPC.html

The Challenge:

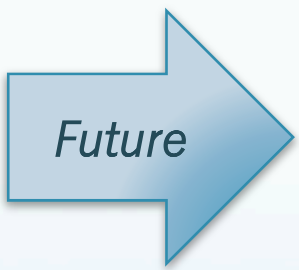
Assuring CIMSS products are available in AWIPS "II"

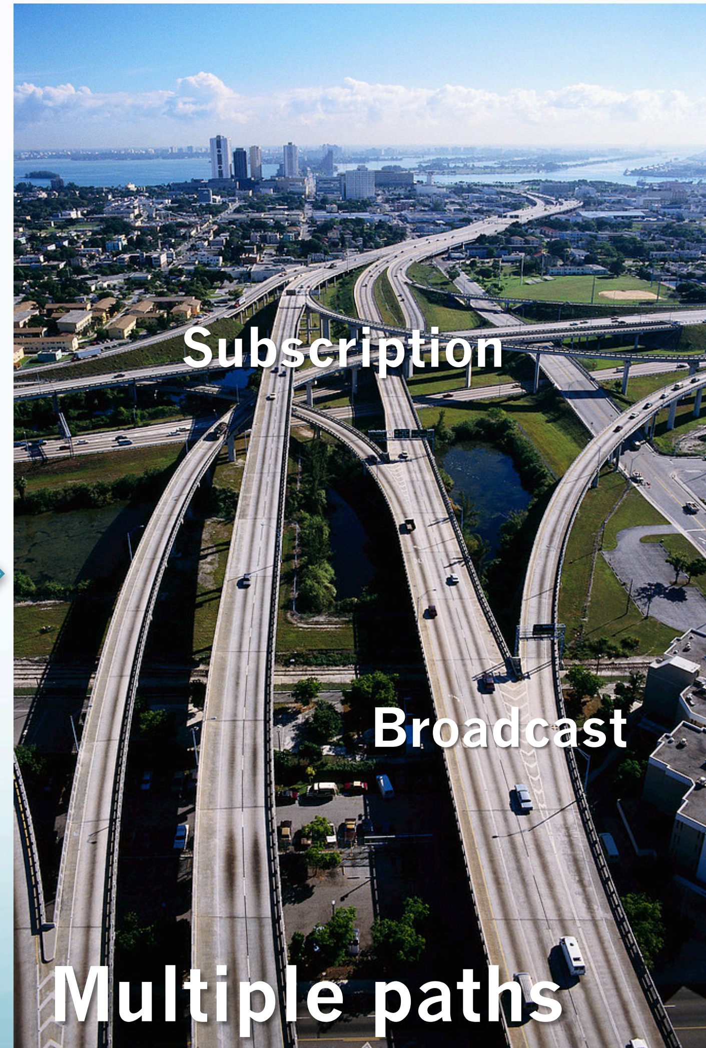


The Roadmap


GOES-R
Launch
New functionality
New configuration
New data distribution format

Diversification of paths for data delivery required





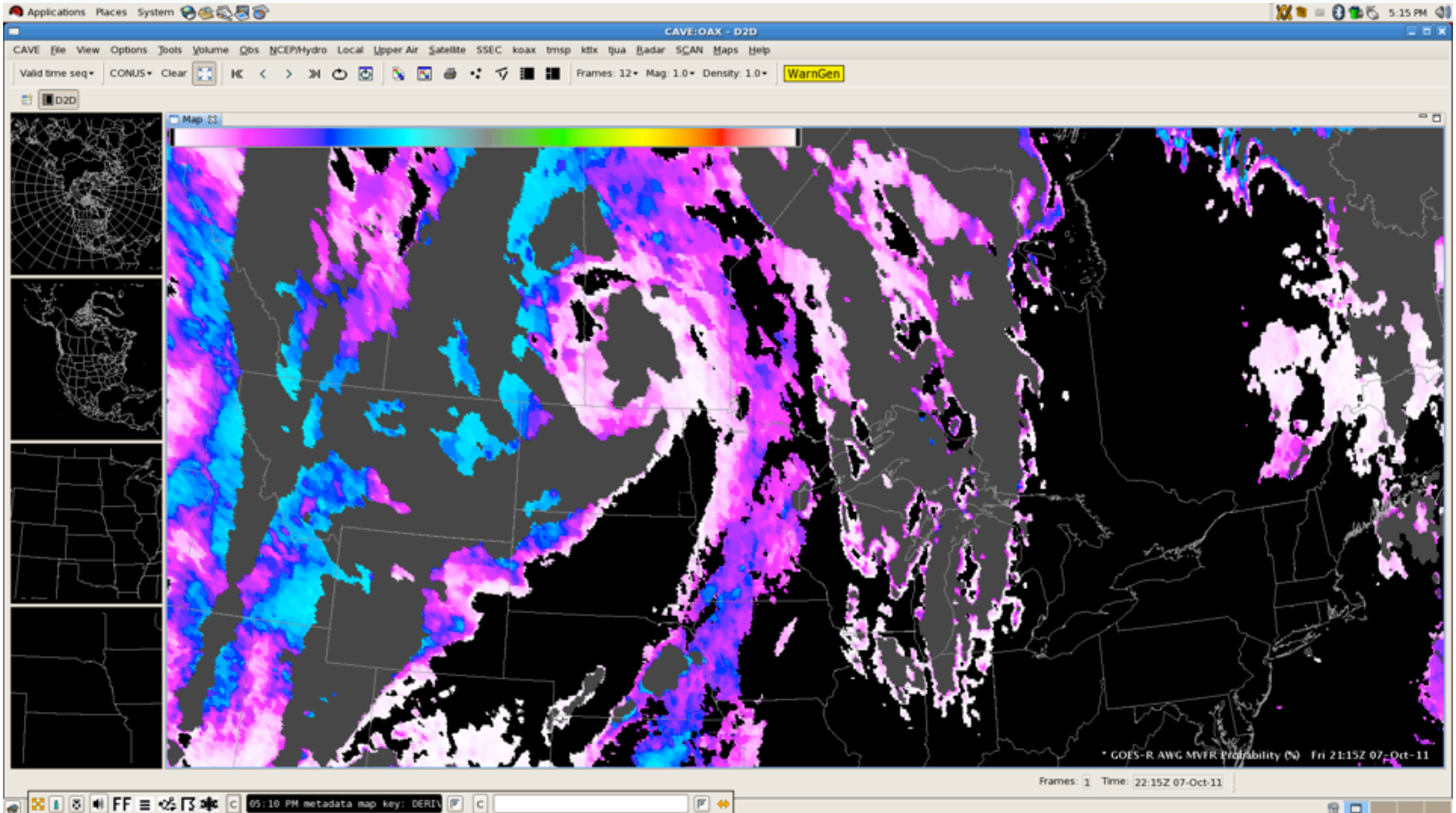
Data Fusion as a Solution

- Data fusion is a methodology current under investigation by NWS OST as a way to solve future information overload by combining different data sets into a more complete, actionable product than any one component separately
- Some GOES-R Algorithm Working Group (AWG) products are already considered fused because they use model output in addition to satellite observations from multiple bands
- If the users are unfamiliar with the inputs into the fused product, misinterpretation of results and underestimate of error may result
  - Data fusion can appear more absolute than it is
- AWIPS II is the ideal tool for data fusion because it can quickly combine disparate data types into a single product and allow for interrogation of original components
- Data fusion should be user developed and controlled

Example: Low Cloud Ceiling Probability

- GOES-R participation in testbeds has indicated that forecasters are interested in evaluating components to assess magnitude, error, and probability rather than a single deterministic solution
  - Convective initiation product
    - Interest in cooling rate as an indicator of realized buoyancy
  - Trend toward model blends and ensembles
    - Evaluating the envelope of solutions
- This summer, NWS Sullivan evaluated the GOES-R AWG Low Cloud Ceiling Probability products, created with existing bands on GOES-East and GOES-West for every scan
  - Developed by Mike Pavolonis and Corey Calvert
  - Daytime fog probability is a function of the spatial uniformity of the 11 μm brightness temperature of the clouds, the temperature difference between the cloud and the surface, and the modeled RH
  - AWIPS II ready

Example:
AWG MVFR Probability (Day)



The *probability of MVFR* product reports the probability that the cloud ceiling is < 3000 feet, **regardless of surface visibility.**

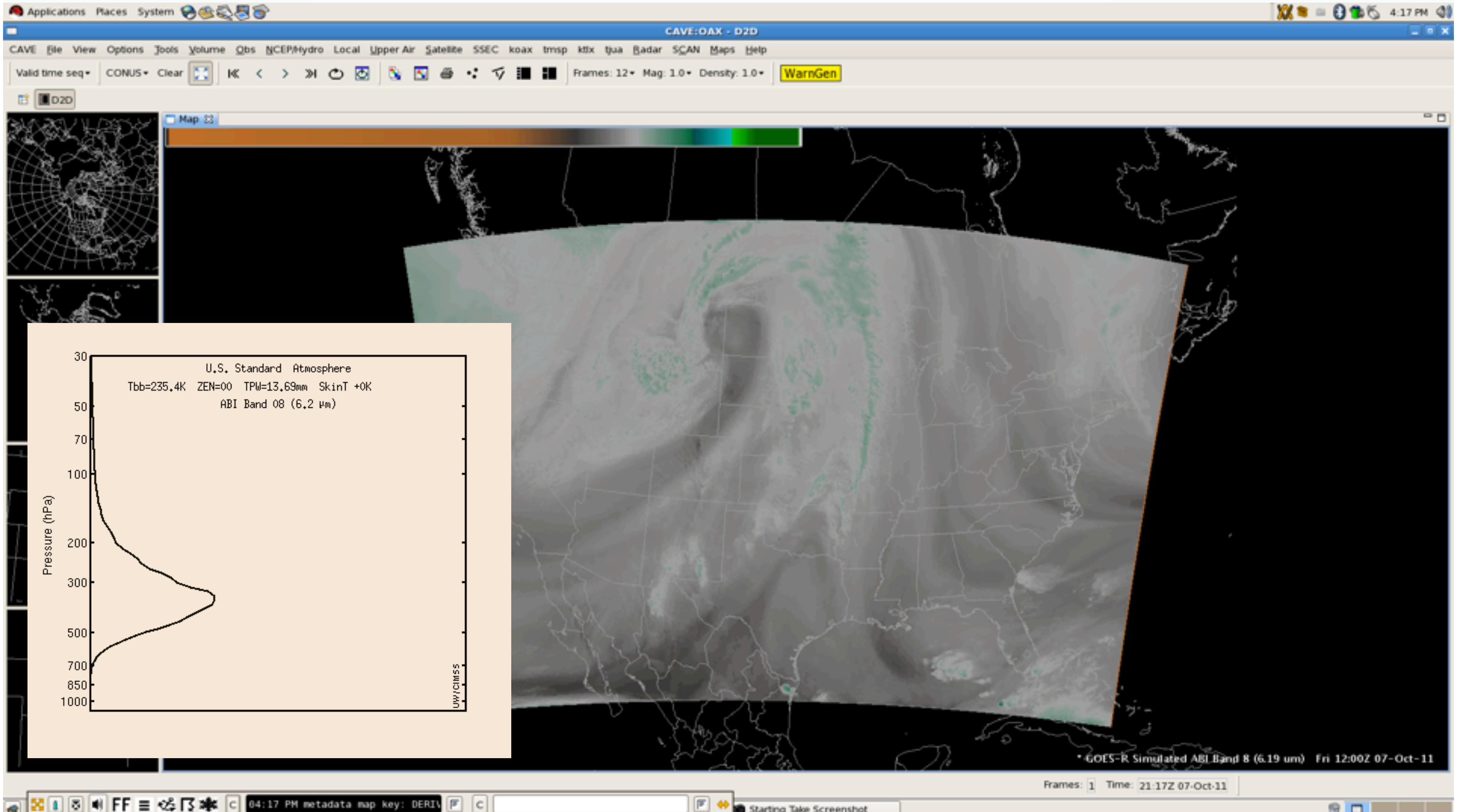
RGB/RGBA Image Compositing

- It is necessary to integrate and support a flexible bit depth data format and user-driven three-way or four-way (with an alpha channel) image blending functionality into the AWIPS II software.
  - Maximizes the use of current and future satellite imagery and products, as well as leverages a red-green-blue-alpha (RGBA) capability in pre-release versions of the migrated software
- The implementation of a data format and display system allowing for bit depths greater than the current specification has numerous applications useful to operational weather analysis and forecasting beyond current capabilities and techniques.
- To support data fusion, image differences, individual bands, and other band manipulations can be assigned to a color in the RGB triplet.

Simulated ABI Longwave Bands

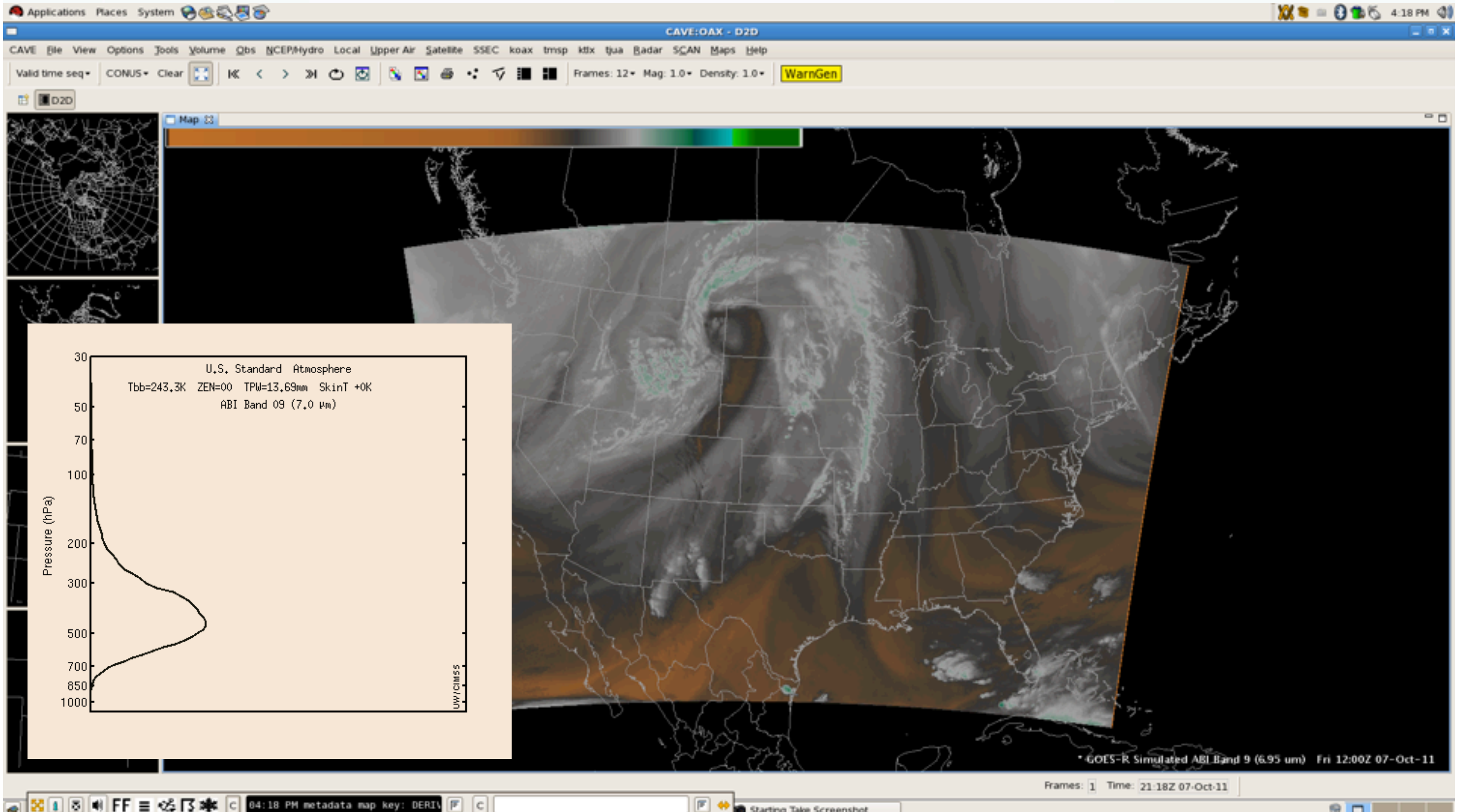
- Bands 8 through 16 are produced from the National Severe Storms Laboratory (NSSL) Weather Research and Forecast (WRF) model output.
- CompactOPTRAN computes optical depths at each model layer based on temperature and water vapor mixing ratio.
- 36-hour simulation at 4 km spatial resolution is started once per day at 00 UTC, with imagery available by 12 UTC.
- Currently limited distribution in AWIPS and N-AWIPS to select NWS forecast offices and National Centers.
- Output available online at http://www.nssl.noaa.gov/wrf/ with imagery at http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/nssl_abi_rt.html

Simulated ABI Band 8 (6.19 μm)



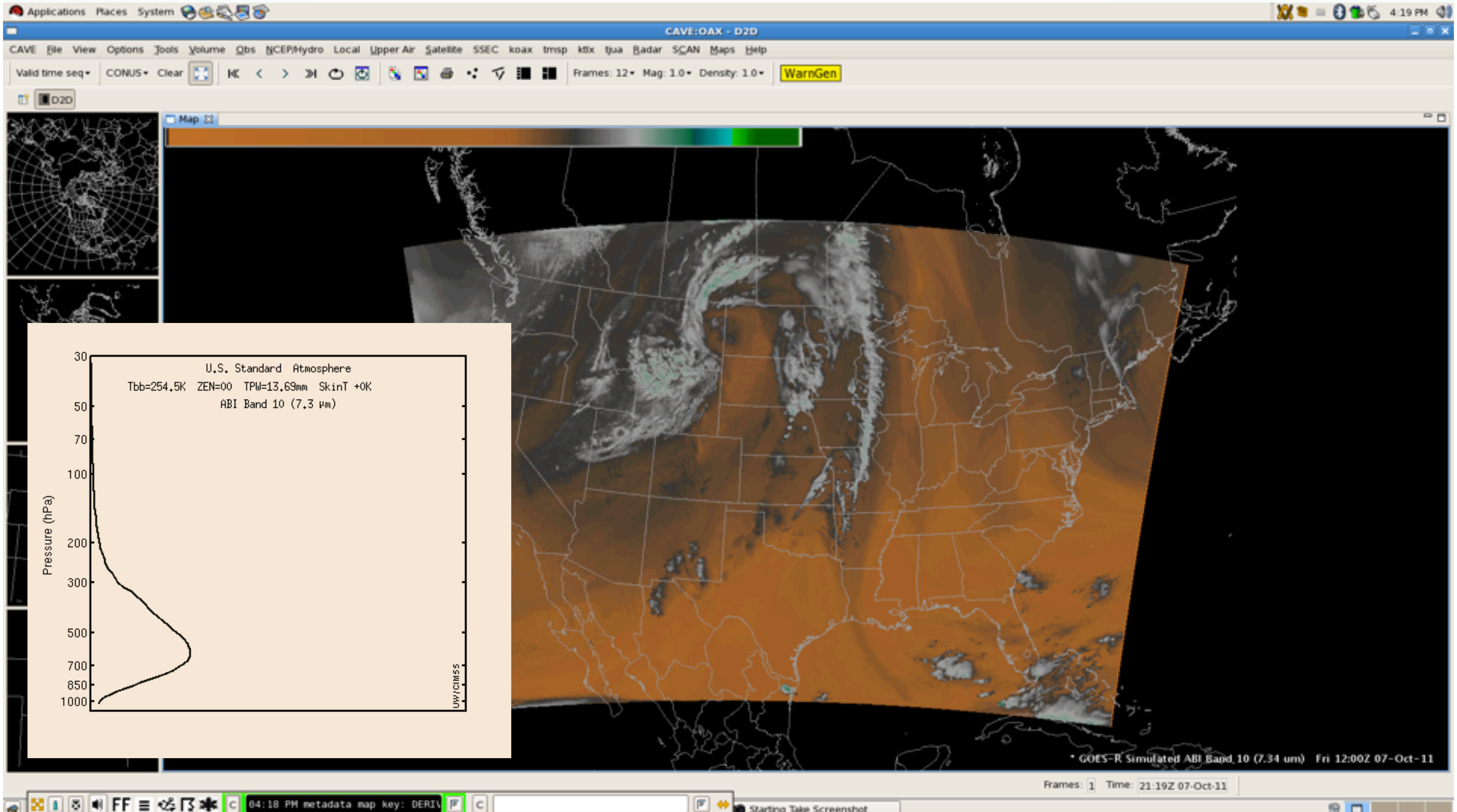
Weighting function for US Standard profile indicates sensitivity to upper tropospheric moisture

Simulated ABI Band 9 (6.95 μm)



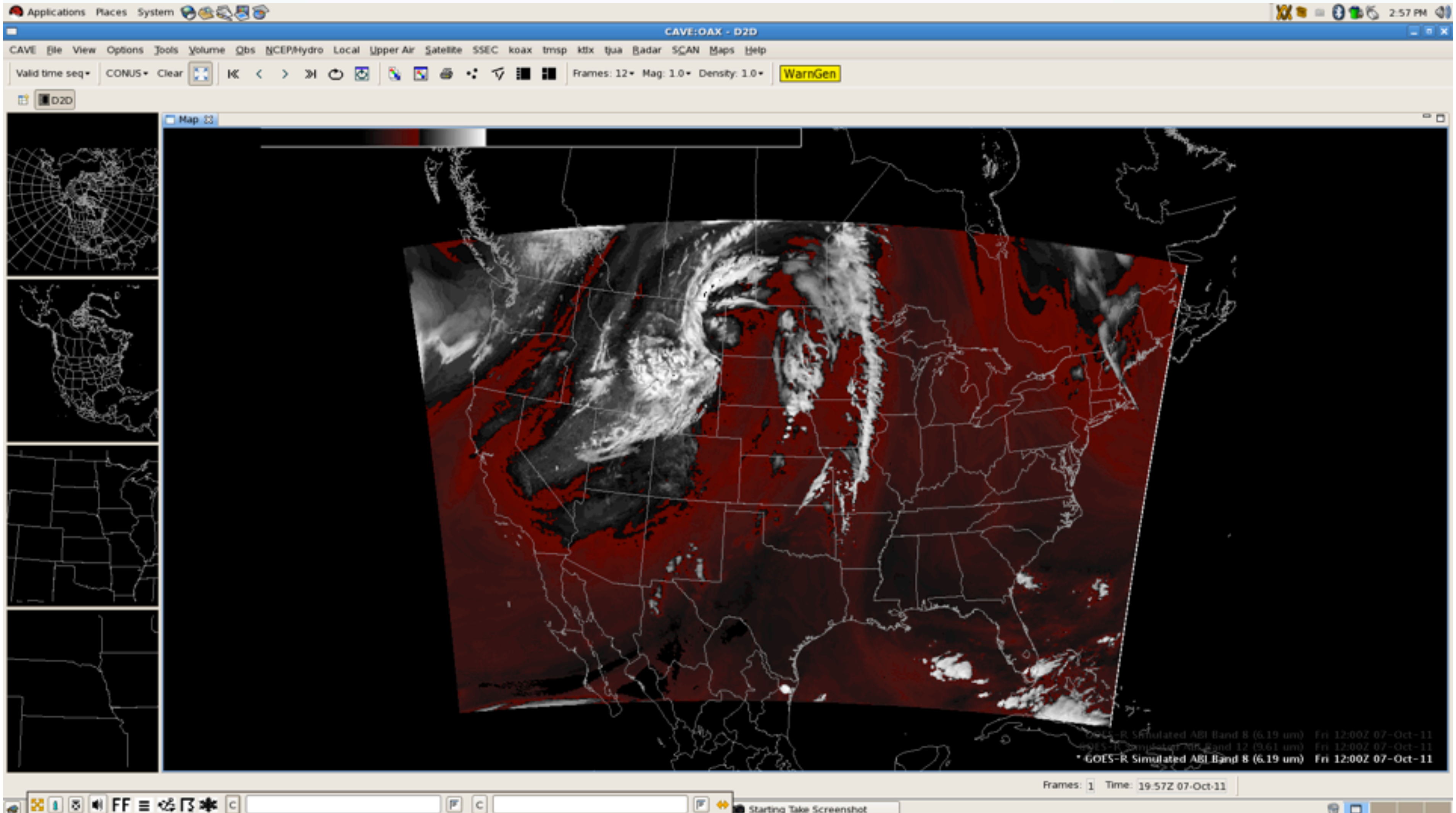
Weighting function for US Standard profile indicates sensitivity to upper middle tropospheric moisture

Simulated ABI Band 10 (7.34 μm)



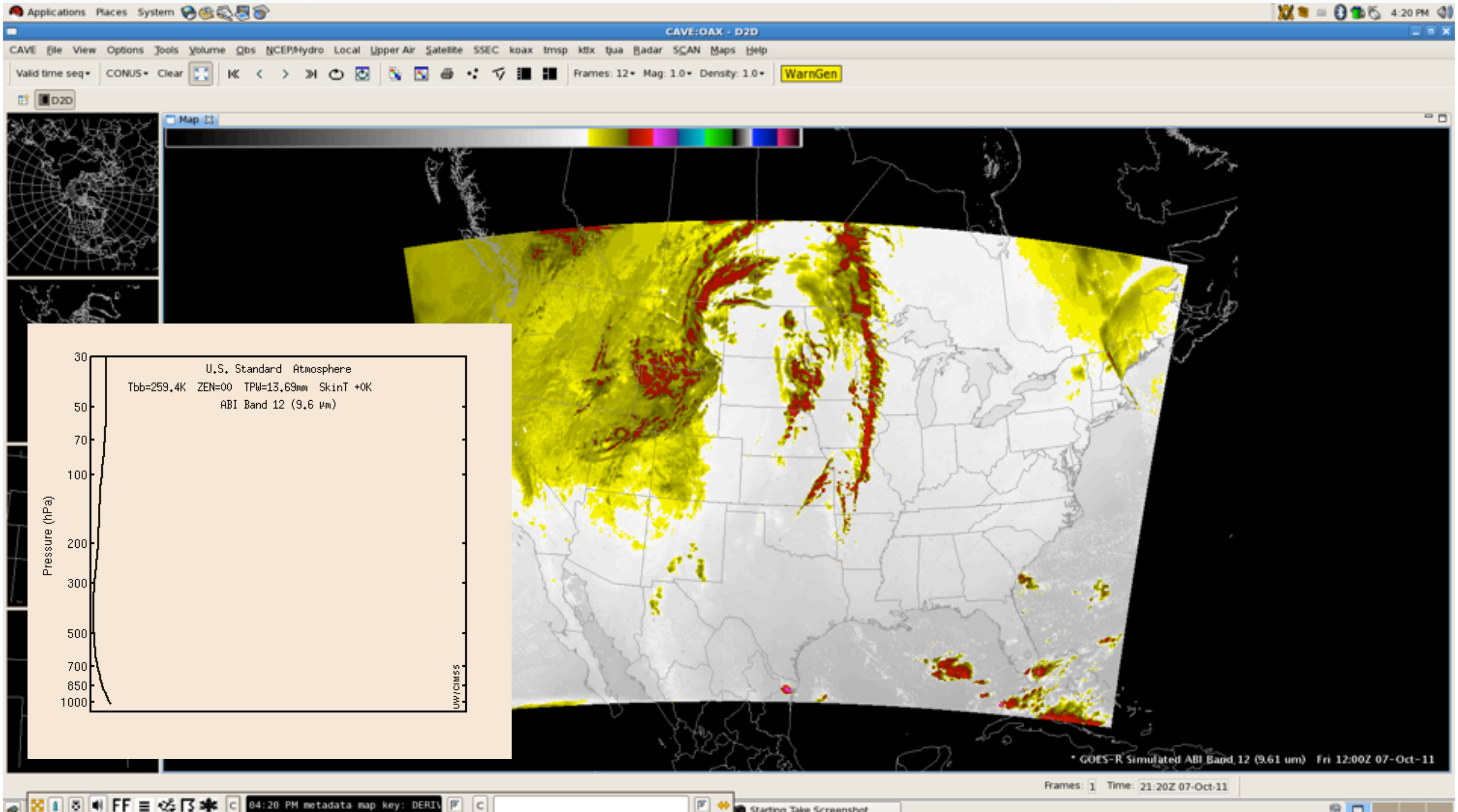
Weighting function for US Standard profile indicates sensitivity to lower middle tropospheric moisture

Building an RGB: Band 8 – Band 10



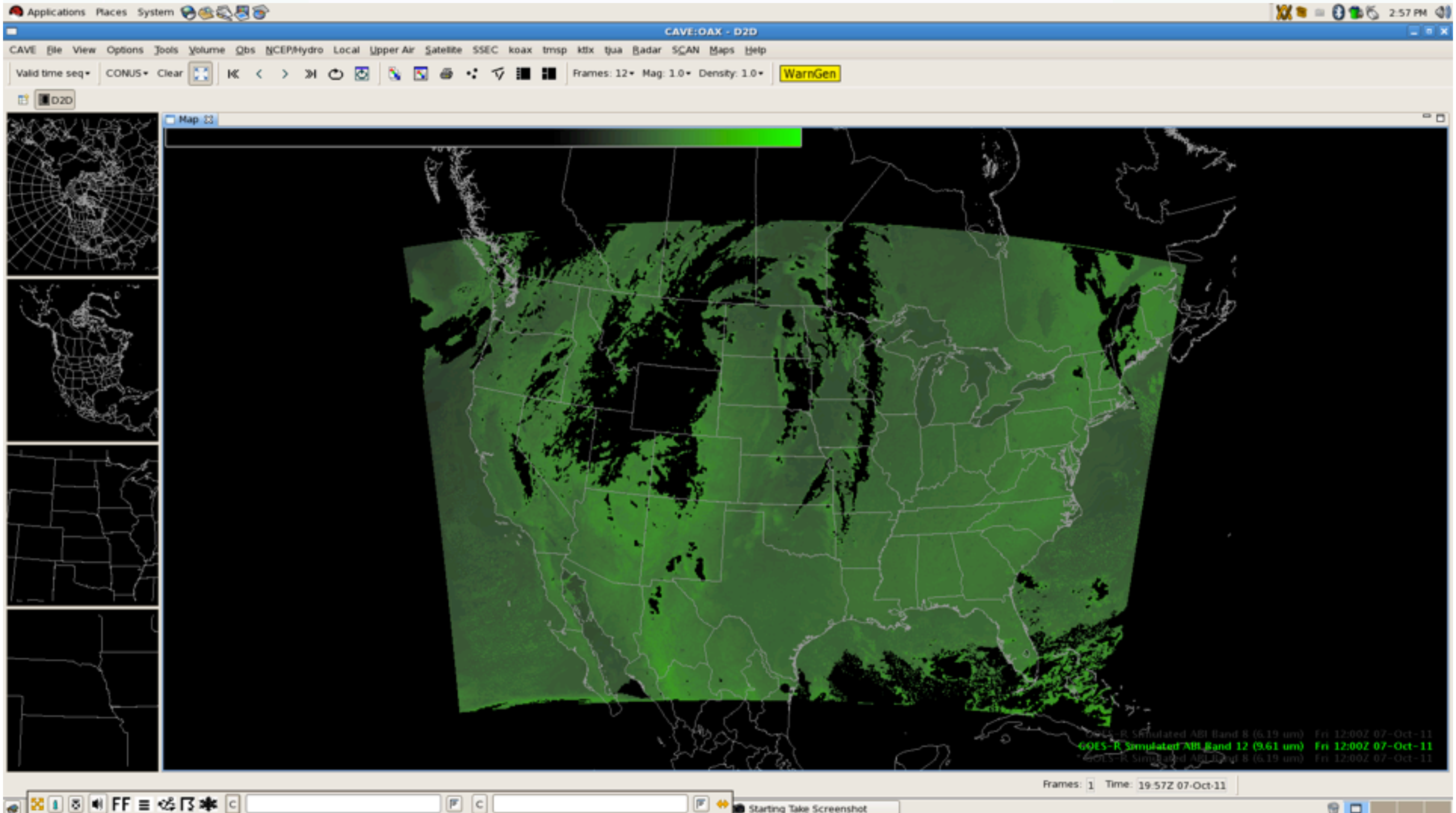
Red with alpha gradient (upper–lower tropospheric moisture difference), white clouds with alpha gradient

Simulated ABI Band 12 (9.61 µm)



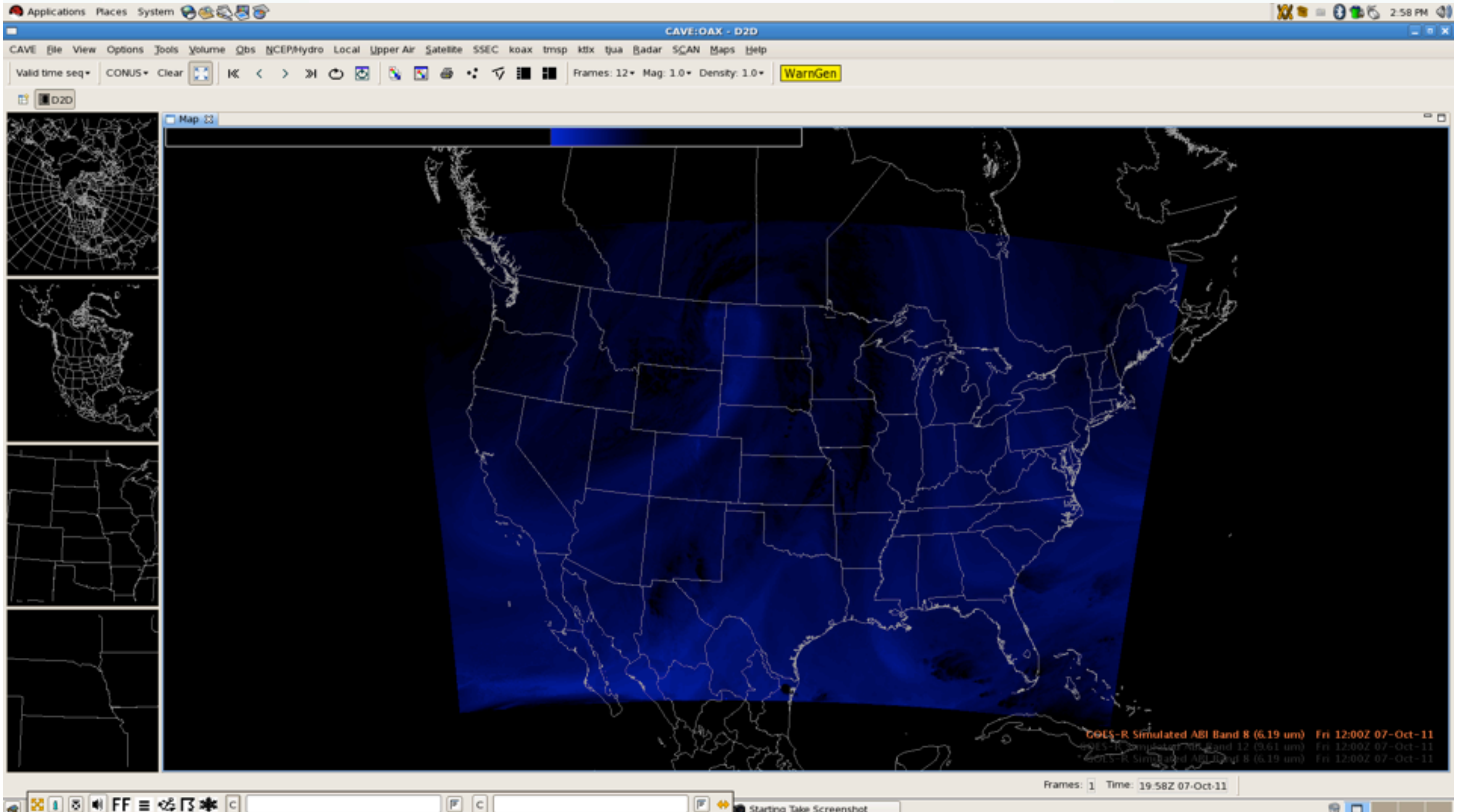
Weighting function for US Standard profile indicates sensitivity to ozone

Building an RGB: Band 12 – Band 13



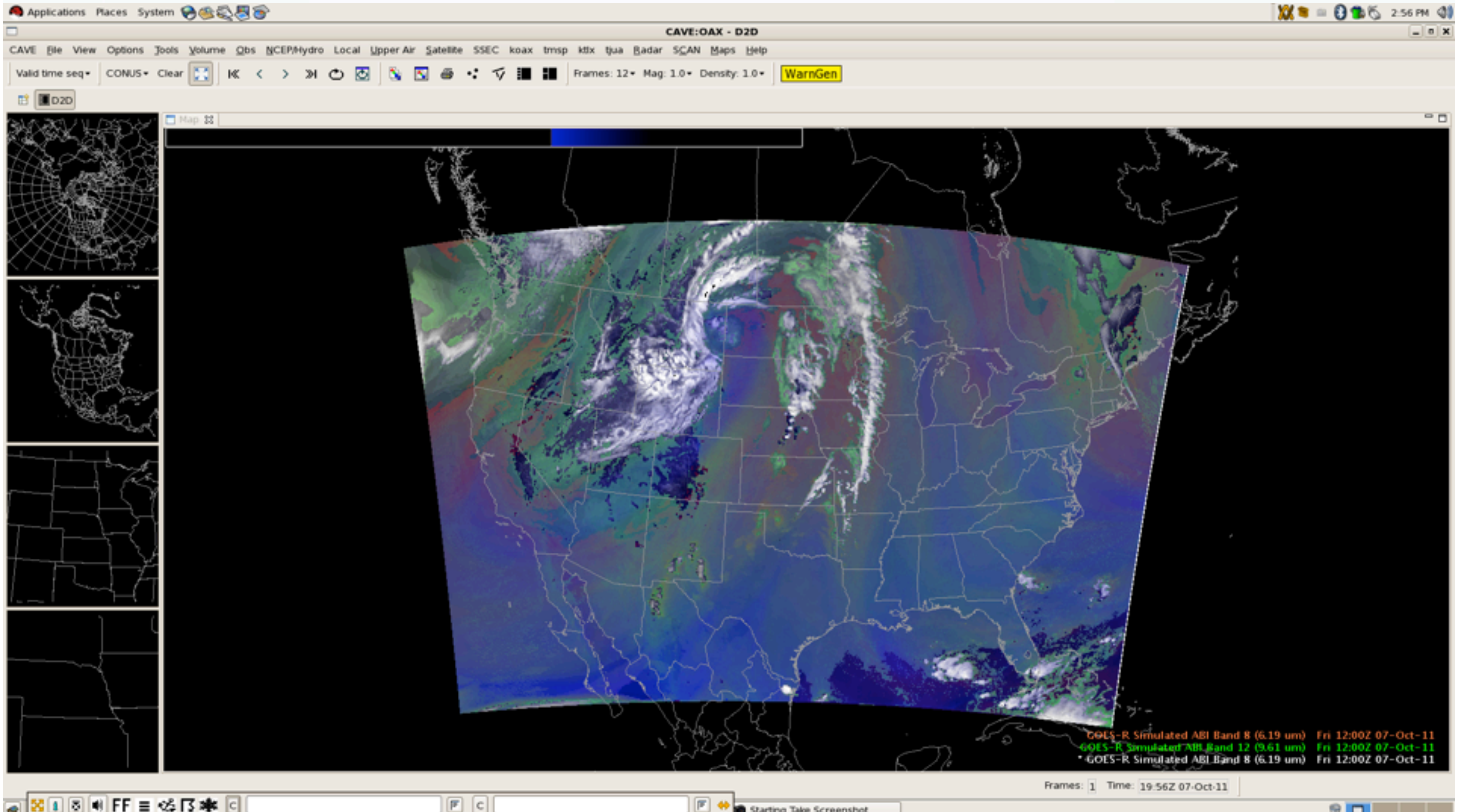
Green with alpha gradient (brighter high ozone concentration indicative of low potential vorticity surfaces)

Building an RGB: Band 8 Inverted



Blue with alpha gradient (brighter blues indicate dryer upper tropospheric air, dry slot)

Building an RGB: Composite

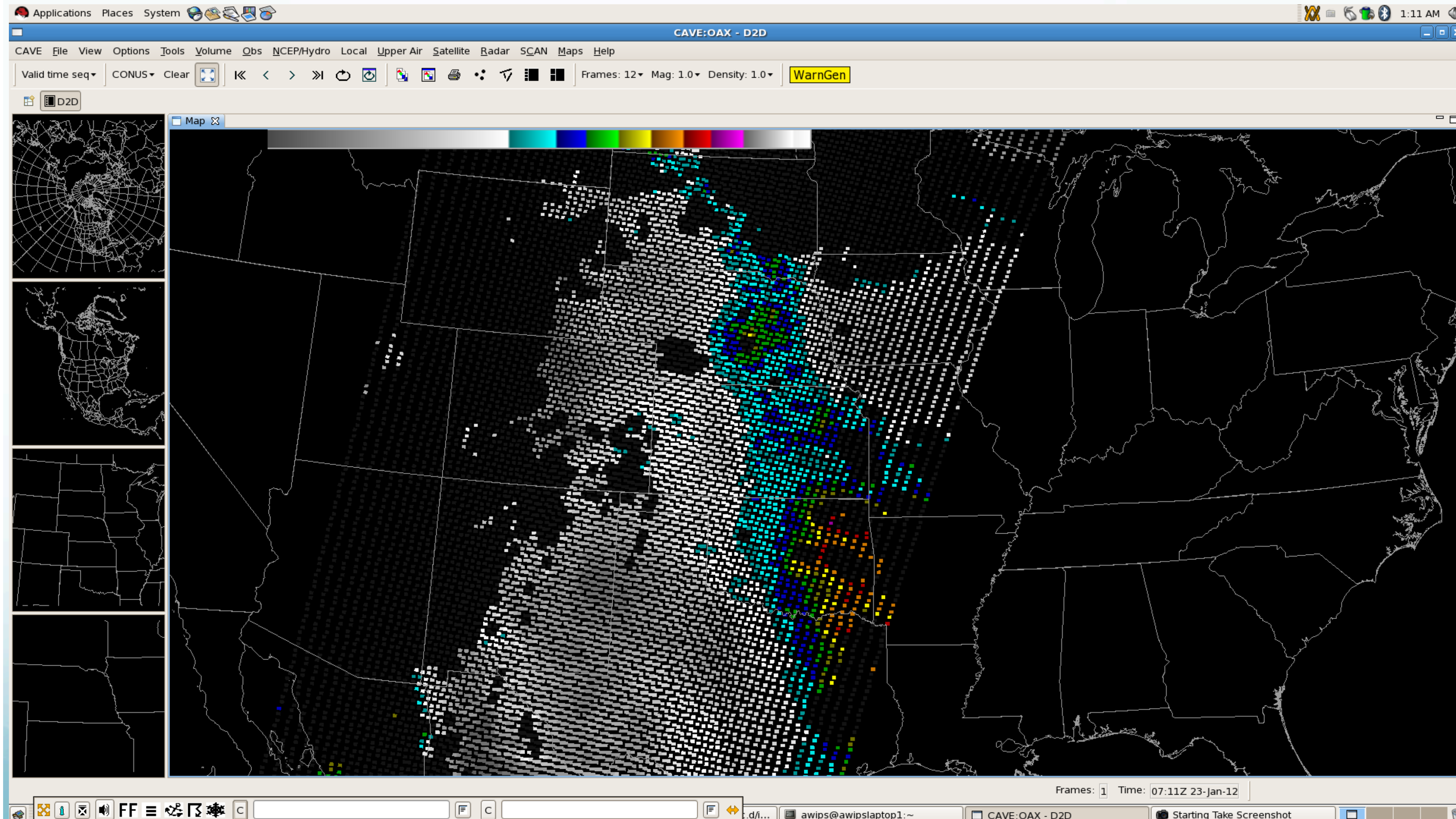


Composite shows an amplified weather pattern, synoptic dry slot, and differential tropospheric moisture

Potential AWIPS II Capabilities

- Point display of satellite-retrieved atmospheric properties
  - Atmospheric Infrared Sounder (AIRS) example
  - Click-to-load profiles?
- User interface for the multi-channel RGB color capability
  - Implement with GPU Shader Language for quick display time, a strength of AWIPS II
- Updated user controls and color scheme selection
  - New color table widget for developing color tables with more than 256 colors (current AWIPS I transmission format and software limitation)
- Product browser capability (Raytheon concept)
  - Redesign the volume browser?

AIRS Retrievals in AWIPS II

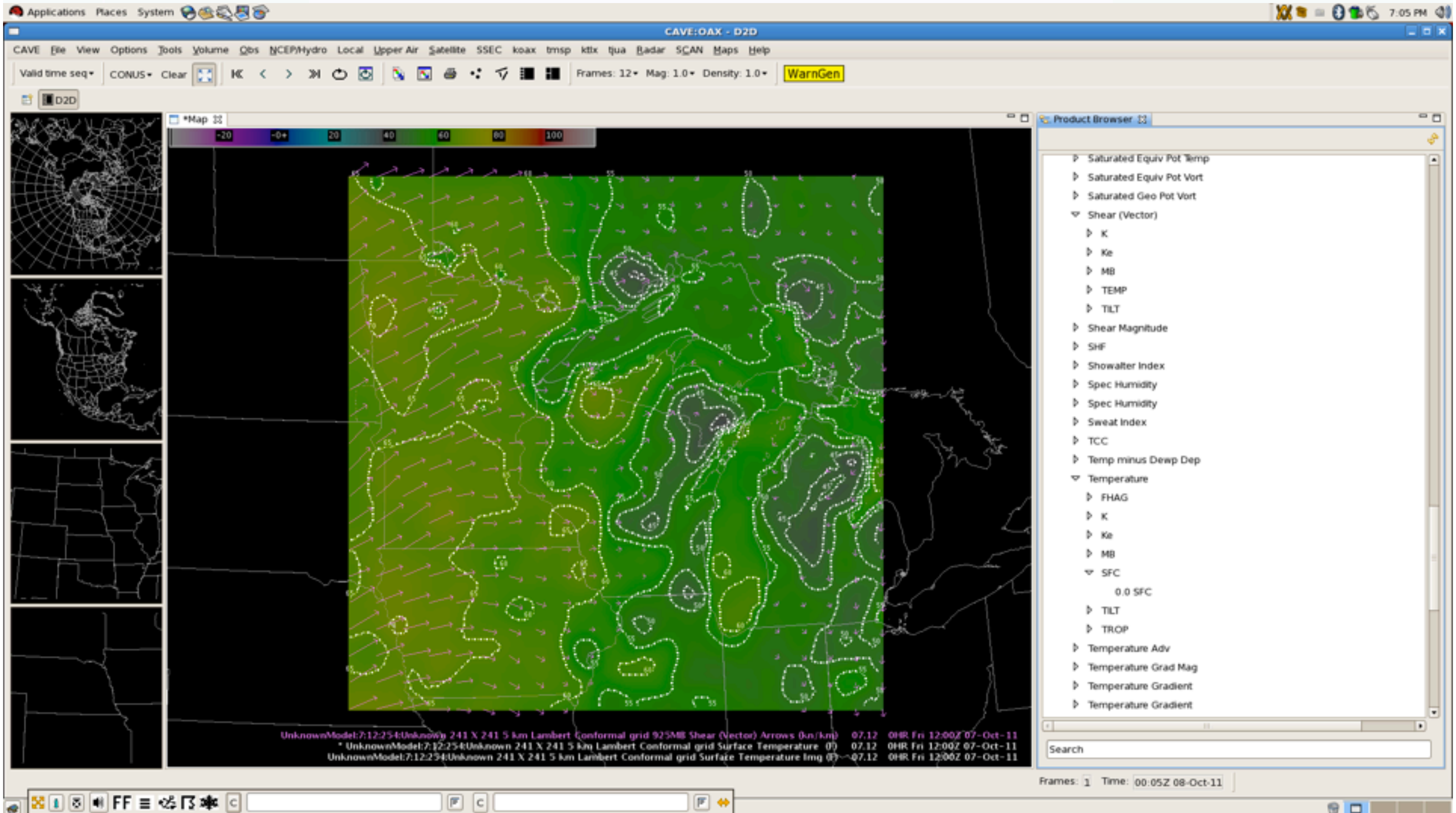


Point retrievals of total precipitable water from AIRS, 8:40 UTC 1 August 2011

Potential AWIPS II Capabilities

- Expanded capability for derived parameters
  - User control of image differencing and scaling
  - Permit operations in value space instead of data storage space
- EDEX plug-in to handle ingest of GOES-R sectorized Cloud and Moisture Imagery (CMI) products in netCDF4
- CAVE plug-in for displaying bit depths greater than eight
  - Partial re-factoring of EDEX plug-ins may be necessary
- Additional configurability via XML
  - Legends, scaling, purging, etc.

Example: Raytheon's Product Browser



CIMSS Real-Time Mesoscale Analysis (CRTMA) using MODIS SST composite

AWIPS II Capabilities Wish List

- Product-push deployment, quick display capability, and direct display sharing with remote users
  - Ability to introduce new or special products just in time for use with high-impact or evolving weather events
  - Facilitate direct communication in training exercises to allow for interaction and quick answers to questions on data or products
- Incorporation of scientific programming languages to leverage display and data store
  - Increase use in research sector and academia
  - Allow for more efficient techniques development
  - Decrease amount of time for training in new language

Conclusions and Future Directions

- The GOES-R Proving Ground is an orchestrated activity which is advancing the use and knowledge of satellite imagery and future products in operational meteorology (NRC requirement #2) borne out of a need to mitigate risk in preparing users for upcoming capabilities (NRC requirement #1).
- AWIPS II will play a significant role in promoting the capabilities of GOES-R and new polar-orbiting satellites (Suomi National Polar-orbiting Partnership) because of
  - New capabilities and flexibility in the software;
  - Expanded distribution and development group/strategy;
  - Ongoing implementation of additional features
    - Maximize the utility of satellite imagery and products in concert with other in-situ observations and model output.
- AWIPS II exceeds NRC resource adequacy requirement #3.

Conclusions and Future Directions

- AWIPS II will also allow for the efficient transfer of new science and technology into NWS operations without delay, so long as sufficient bandwidth is provided.
  - Limited broadcast, increased subscriptions for smart push/pull
- Our future AWIPS will not be confined to NWS offices, but extend to universities and other agencies, becoming an integral communication tool and stimulating research to operations activities, sustaining a continuous feedback loop (NRC requirement #4).
  - Unique applications of the software will increase
- Facing future data overload, a methodology is necessary which optimizes the use of data, imagery, products, and tools which are situation and scenario relevant, leading the decision support thought process.
  - Don't let data fusion become data *con*fusion

Questions? Comments?

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