Software Tools Useful for Image Enhancement and Analysis:
An update on HYDRA and its integration into McIDAS-V

In response to Recommendation 35.15, CGMS satellite operators to consider making a data interface available such as ADDE servers for that McIDAS-V and HYDRA can be applied to their data.

HYDRA – the HYper-spectral data viewer for Development of Research Applications is a freeware multispectral data analysis tool for satellite data. HYDRA was developed to assist research and development of remote sensing applications as well as education and training of remote sensing scientists. HYDRA provides an interface that allows users to explore and visualize relationships between radiances (or reflectances and brightness temperatures) and wavelength (or wavenumber) using spectra diagrams, cross sections, scatter plots, multi-channel combinations, and color enhancements on a pixel by pixel basis with full access to the underlying metadata of location and time.

HYDRA enables interrogation of multispectral (and hyperspectral) fields of data so that (a) pixel location and spectral measurement values can be easily displayed; (b) spectral channels can be combined in linear functions and the resulting images displayed; (c) false color images can be constructed from multiple channel combinations; (d) scatter plots of spectral channel combinations can be viewed; (e) pixels in images can be found in scatter plots and vice versa; (f) transects of measurements can be displayed, and (g) soundings of temperature and moisture as well as spectra from selected pixels can be compared.

A project is well underway at the University of Wisconsin SSEC to develop the fifth generation of McIDAS, a Java-based, freely available, open-source system for multispectral and hyperspectral researchers and algorithm developers that will provide powerful new data manipulation and visualization tools to work in this data rich environment. A major component of the McIDAS-V environment is the integration of HYDRA into its software toolkit to add greatly increased interactive data interrogation capabilities to the existing McIDAS functionality. Conversely, integrating HYDRA into this toolkit takes advantage of the great flexibility in analysis and display already within McIDAS-V. NASA EOS MODIS and AIRS data as well as MSG SEVERI and METOP IASI data are now being used in conjunction with in situ and gridded data to develop new analysis and product validation techniques in the McIDAS-V environment.

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An update on HYDRA and its integration into McIDAS-V

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1. Overview

The Man computer Interactive Data Access System (McIDAS) project began over 30 years ago at the University of Wisconsin-Madison to analyze and visualize data from the first generation of geostationary weather satellites. McIDAS continues to provide a strong data analysis and visualization capability for the current environmental satellites. However, the next generation of operational remote sensing instruments under development require software tools with expanded capability and performance to support innovative techniques for developing algorithms, visualizing data and products, and evaluating results. A project is well underway at SSEC to develop the fifth generation of McIDAS, a Java-based, freely available, open-source system for multispectral and hyperspectral researchers and algorithm developers that provides powerful new data manipulation and visualization tools to work in this data rich environment. A major component of the McIDAS-V environment is the integration of the Hyper-spectral data viewer for Development of Research Applications (HYDRA) into its software toolkit to add greatly increased interactive data interrogation capability to the existing McIDAS functionality. NASA EOS MODIS and AIRS data as well as MSG SEVERI and METOP IASI data are now being used in conjunction with in situ and gridded data to develop new analysis and product validation techniques in the McIDAS-V environment.

2. Background on HYDRA

The HYDRA software grew out of the need to provide research scientists and educators with freely available software that could display and analyze remotely sensed multispectral and hyperspectral data. HYDRA is a third generation application for hyperspectral data produced at the SSEC/CIMSS. The first two were based on commercial packages IDL and Matlab and served as a testbed to refine the operations and functionality required by the users. The integration of HYDRA into McIDAS-V allows the capabilities of HYDRA to be combined with the existing powerful tools that make up McIDAS-V.

The primary design requirements of HYDRA were that the software must be freely available to the global community, computer platform independent, and extendable. Computer platform independence had been elusive in so far as HDF libraries still are required to view the data, but the McIDAS-V compatible version of HYDRA will take advantage of the NetCDF4-Java library removing the necessity of special HDF native code. It was also important that the toolkit be coded in an easy-to-use scripting language, so that users could modify and extend the capabilities as needed. The VisAD (Visualization for Algorithm Development) Java library was selected as the basis for HYDRA. This library allows applications to be written in

either Java or Jython, the Java implementation of the popular Python scripting language. More information on VisAD is given below.

3.   Background on McIDAS-V

The Man-computer Interactive Data Access System (McIDAS) has its origins in the early 1970's. The software have been updated as far as possible over time, most recently in the early 1990's to run McIDAS in the UNIX environment. The data analysis and visualization capabilities of this system remain powerful such that even 35 years later the software is used by many atmospheric scientists in research, operations and industry. Three years ago, scientists and programmers at SSEC formed a development team to bring the McIDAS concept to a modern and more versatile computing environment. Named McIDAS-V for the 5th generation of the McIDAS software, this evolutionary leap will provide powerful new capabilities for data analysis and visualization to support scientists developing products for the next generation of environmental satellites.

The requirements for McIDAS-V include full support for current generation McIDAS users, software that is easy to install with an easy to use interface, powerful data analysis tools, access to a wide array of weather satellite and other environmental data, and high quality documentation and training materials. The software is open source and freely available.

The development path of McIDAS-V integrates several software tools and new ideas into its' environment, the most recent being HYDRA. The McIDAS-V toolkit consists of the following software, which are described in more detail below.

VisAD – Visualization for Algorithm Development
IDV – Integrated Data Viewer
HYDRA - HYperspectral-viewer for Development of Research Applications
McIDAS-X to -V Bridge – moving –X output to the new McIDAS-V environment
New Development – building new tools for researchers

VisAD

The foundation of McIDAS-V is the Visualization for Algorithm Development (VisAD), an open source, Java library for building interactive and collaborative data analysis and visualization tools (see http://www.ssec.wisc.edu/~billh/visad.html). Developed by Bill Hibbard at UW-Madison/SSEC in the 1990's, VisAD is used by a wide variety of scientists and others seeking a powerful data analysis software tool. VisAD combines several important attributes, including,

*   the use of Java for platform independence,
*   a powerful mathematical data model that embraces virtually any numerical data set
*   a general display model that supports 2-D and 3-D displays, and including multiple data views with direct manipulation
*   metadata that is integrated into each data object

* adapters for multiple data formats (NetCDF, HDF-5, FITS, HDF-EOS, McIDAS, Vis5D, etc.) and access to remote data servers through HTTP, FTP, DODS/OPeNDAP, and OPENADDE protocols

The core of the VisAD library is a unified Data Model, which allows for the representation of literally any numeric data in a consistent manner. This is very important when integrating data from a variety of sources that may have different sampling topologies in space or time. The Data Model also has built-in metadata for parameters such as units and error estimates. Because these metadata are an integral part of the data means they can be easily used to verify the validity of computations (the software detects invalid combinations, such as adding a temperature to a pressure) and to estimate the reliability of computations.

IDV

The Integrated Data Viewer (IDV) is also an open source, Java based software framework developed at Unidata that builds upon the VisAD library to provide a versatile data analysis and visualization toolkit for geoscience data. The IDV brings together the ability to display and work with satellite observations, surface and upper air (radiosonde) observations, gridded data, and radar and profiler data, all within a unified interface. The VisAD/IDV visualization capability provides 3-D views of the atmosphere and allows users to interactively slice and probe the data, creating cross-sections, profiles, animations and value read-outs of multi-dimensional data sets. The software is freely available from Unidata under the terms of the GNU Lesser General Public License (http://www.unidata.ucar.edu/software/idv/). Figure 1 shows an example of a 3 dimensional rendering of temperature and wind fields over the U.S., while Figure 2 shows an IDV 3-dimensional display of data from consecutive overpasses of A-Train instruments MODIS and CALIPSO.

4. Multi-Channel Viewing and Hyperspectral Data Analysis with the McIDAS-V HYDRA component

The Multi-Channel Viewer within McIDAS-V enables display and interrogation of the spectral channel values for any pixel within a given data set. Measurements values (in radiance or reflectance or brightness temperature as selected) can be displayed for individual pixels within the granule; transects from one location to another can be constructed for a given spectral channel to determine min/max values as well as gradients in between. The Channel Combinations Tool allows the user to generate scatter plots of one set of channel combinations versus another. The values within the scatter plot can be located in the multi-channel images and conversely regions within the multi-channel image can be displayed in the scatter plot. This is very useful in locating features in the images and determining threshold values for discriminating them from the rest of the image (e.g. clear sky versus cirrus clouds).

In Figure 3, the McIDAS-V HYDRA display shows the user has selected a METOP IASI granule (top), and the user has selected two locations on the image to display the full IASI spectra (bottom). The user can move the slider bar on the spectra display to change the image in the top display, thereby allowing powerful user interaction with the entire IASI granule data.

In Figure 4, simulated data from the forthcoming GOES-R Advanced Baseline Imager (ABI) is displayed. The simulated data sets help algorithm developers to develop products for immediate use upon launch and operational deployment of space-based instruments. The left panel of this McIDAS-V display shows an image from the ABI band 11 (8.5 um); the center panel shows an image from band 14 (11 um) and the right panel shows a scatter plot from the two bands; the X-axis is the 11 um brightness temperature and the Y-axis is the difference between band 8 and band 11 (BT8-BT11). Differencing these two channels enables the scientist to separate water cloud from ice cloud. The McIDAS-V user can use the cursor to draw a rubber band box over a region, such as off the west cost of California, to display those pixels in the scatter plot corresponding to those within the box. The user can also draw a rubber band box in the scatter plot and colorize the pixels in the image. These data interrogation tools allow users to interactively examine single pixel brightness temperature values for a spectral band or combination of spectral bands.

Figure 5 demonstrates the Transect capability in McIDAS-V, the user interactively stretches or slides the transect line around the image, the image field values of radiance or brightness temperature are automatically resampled to the drawn line and displayed.

Finally, Figure 6 shows an AIRS spectra at two different geographic locations, where the scientist has zoomed in to display individual water vapor absorption lines. These operations are the same for any hyper-spectral instrument.

5.   Summary

These examples illustrate that the HYDRA capabilities combined with the existing software components of McIDAS-V offers greatly expanded functionality and an easy to use interface. McIDAS-V, through the integration of HYDRA, provides tools to interrogate multispectral and hyperspectral remote sensing data quantitatively and to explore the correlations between radiance measurements and features in the images. Continued development over the next several years is planned in order to incorporate more multispectral and hyperspectral instrument systems into the HYDRA domain. In addition several improvements will be added including (1) improving the user interface, (2) adding the capability to animate sequences in time or wavenumber, (3) introducing a state saving device (i.e. a persistence mechanism), (4) enhancing collaboration at remote sites through granule sharing, (5) enabling more high-spectral data analysis (i.e. principal component analyses), and (6) providing more interaction between scripting and the application.

The HYDRA integration into McIDAS-V is an on-going development effort. More information and the freely available software may be found at: http://www.ssec.wisc.edu/mcidas/v/.

Acknowledgements
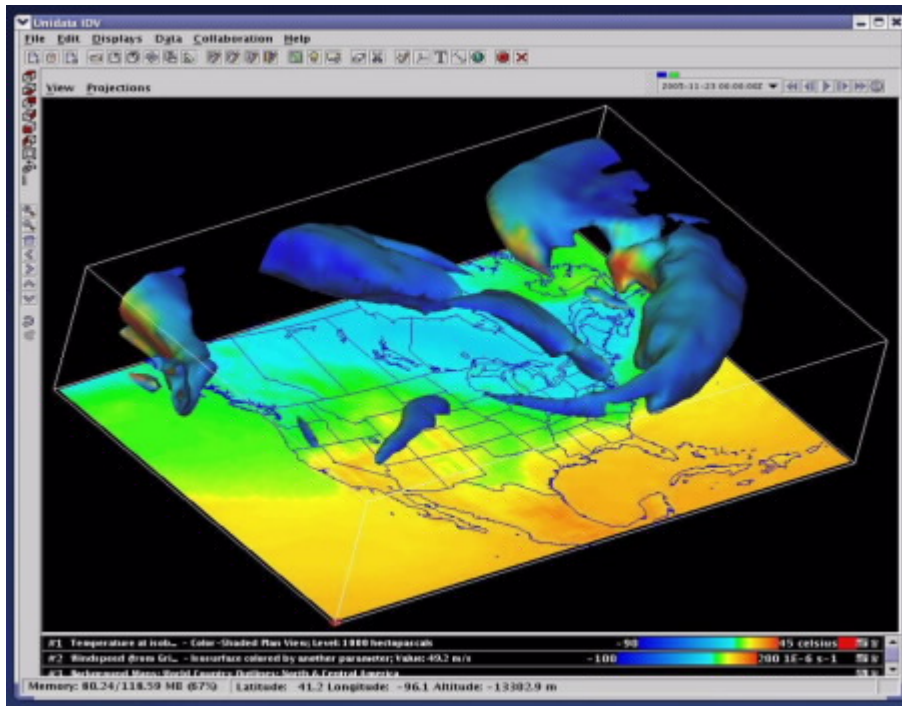
Figures and captions

Figure 1: IDV rendering of color enhanced 850mb temperature field with 3D wind field greater than 50 kts.
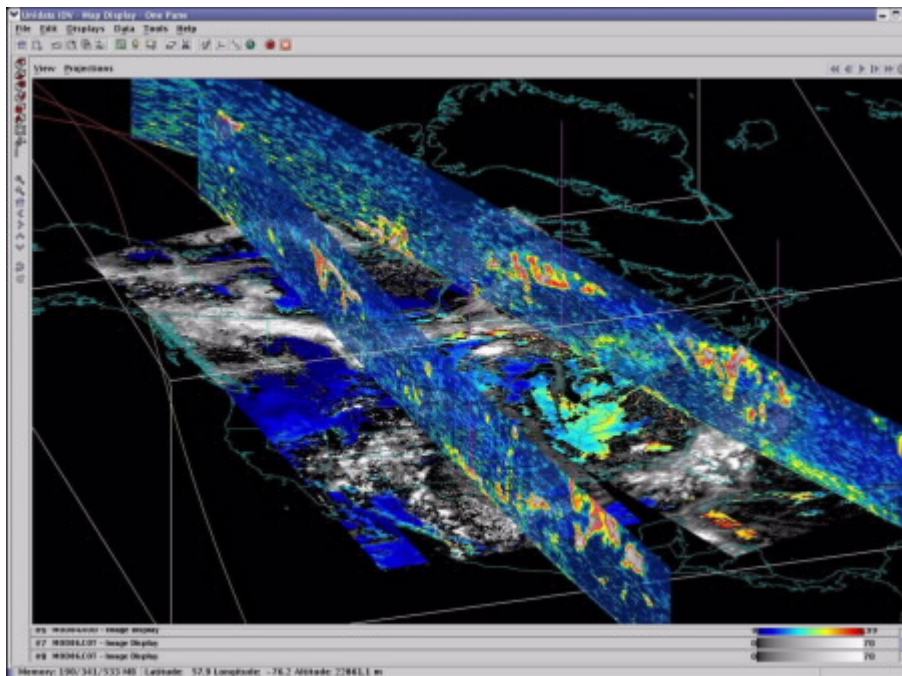

Figure 2: Consecutive overpasses from MODIS (base image, color enhanced 11 um channel) and CALIPSO (cross section of lidar cloud backscatter information).
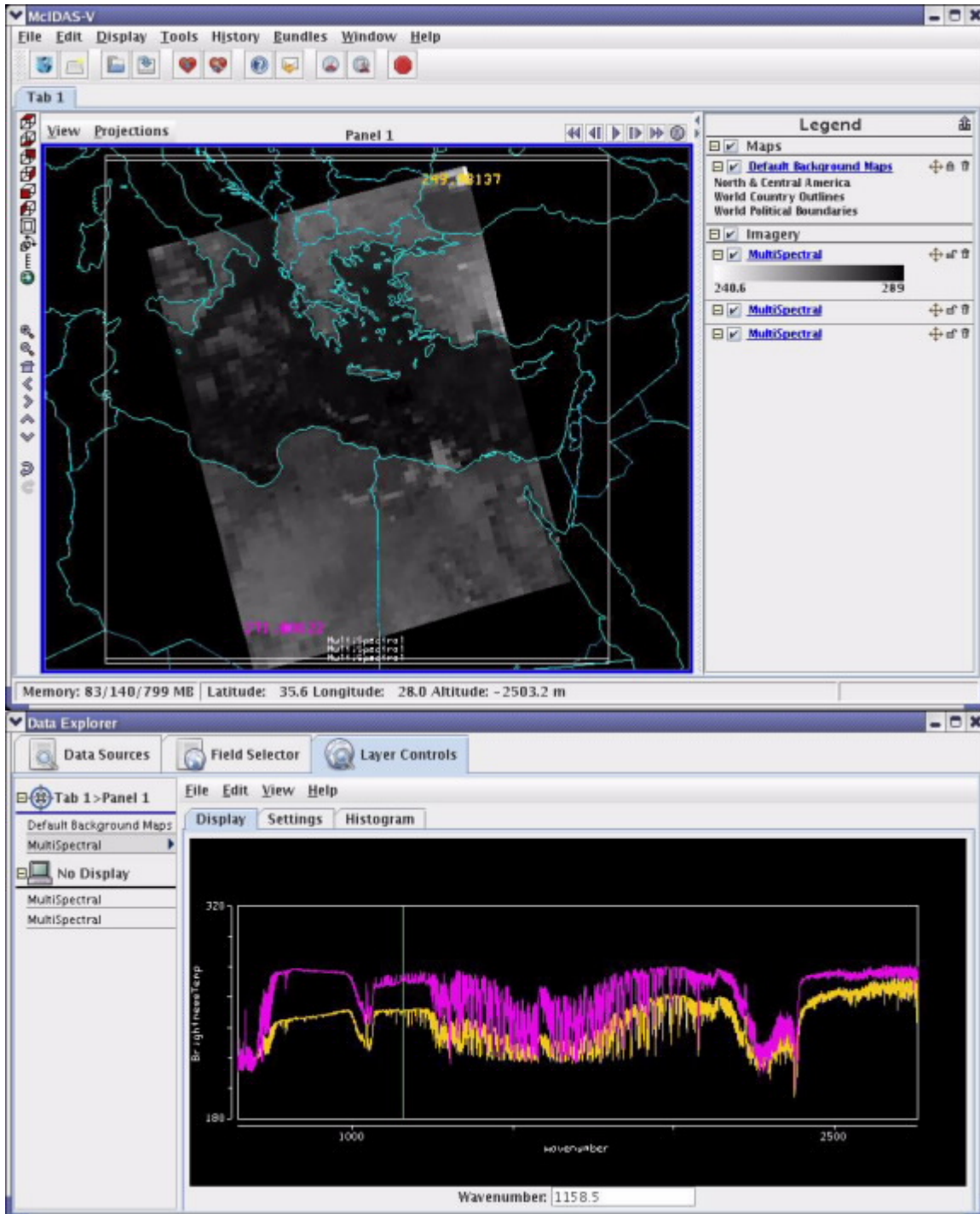
Figure 3: McIDAS-V HYDRA displays of a METOP IASI granule window channel image (top) and user selected locations for display of the associated spectra for that field of view.
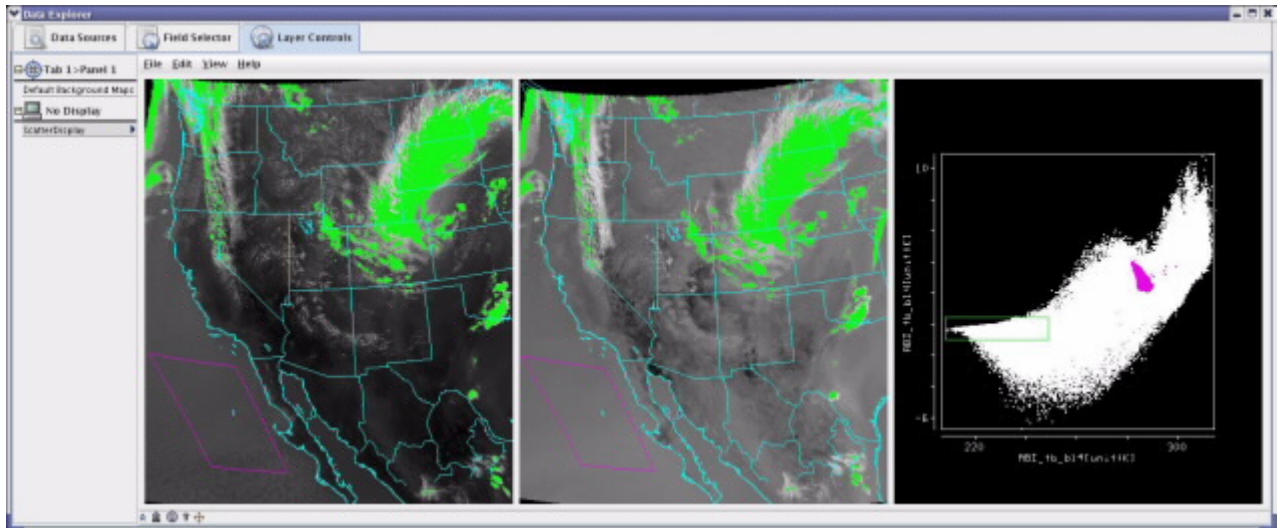
Figure 4: The user has selected two GOES-R ABI spectral bands (left and center) and displayed a scatter plot of the channel differences vs. one channel brightness temperature. The user can identify a group of pixels with the cursor and color enhance those pixels on the imagery or within the scatter plot, thereby identifying specific features from the data.
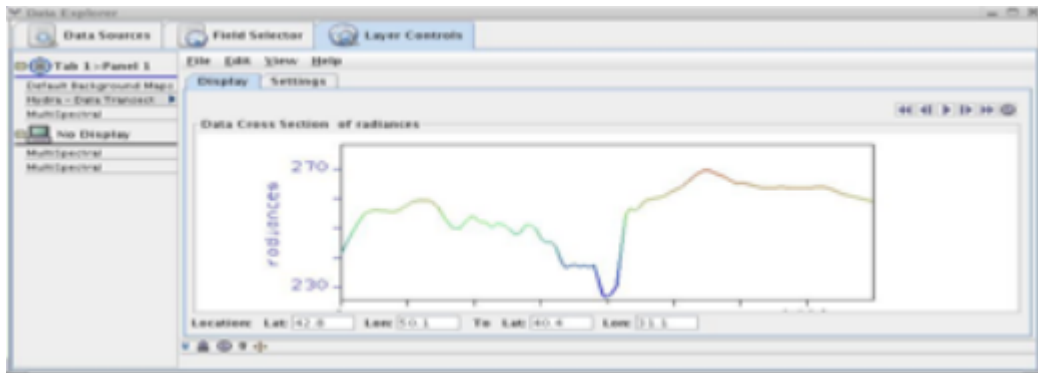

Figure 5: Transect Example in McIDAS-V, line plot of re-sampled image values along the user drawn line below.
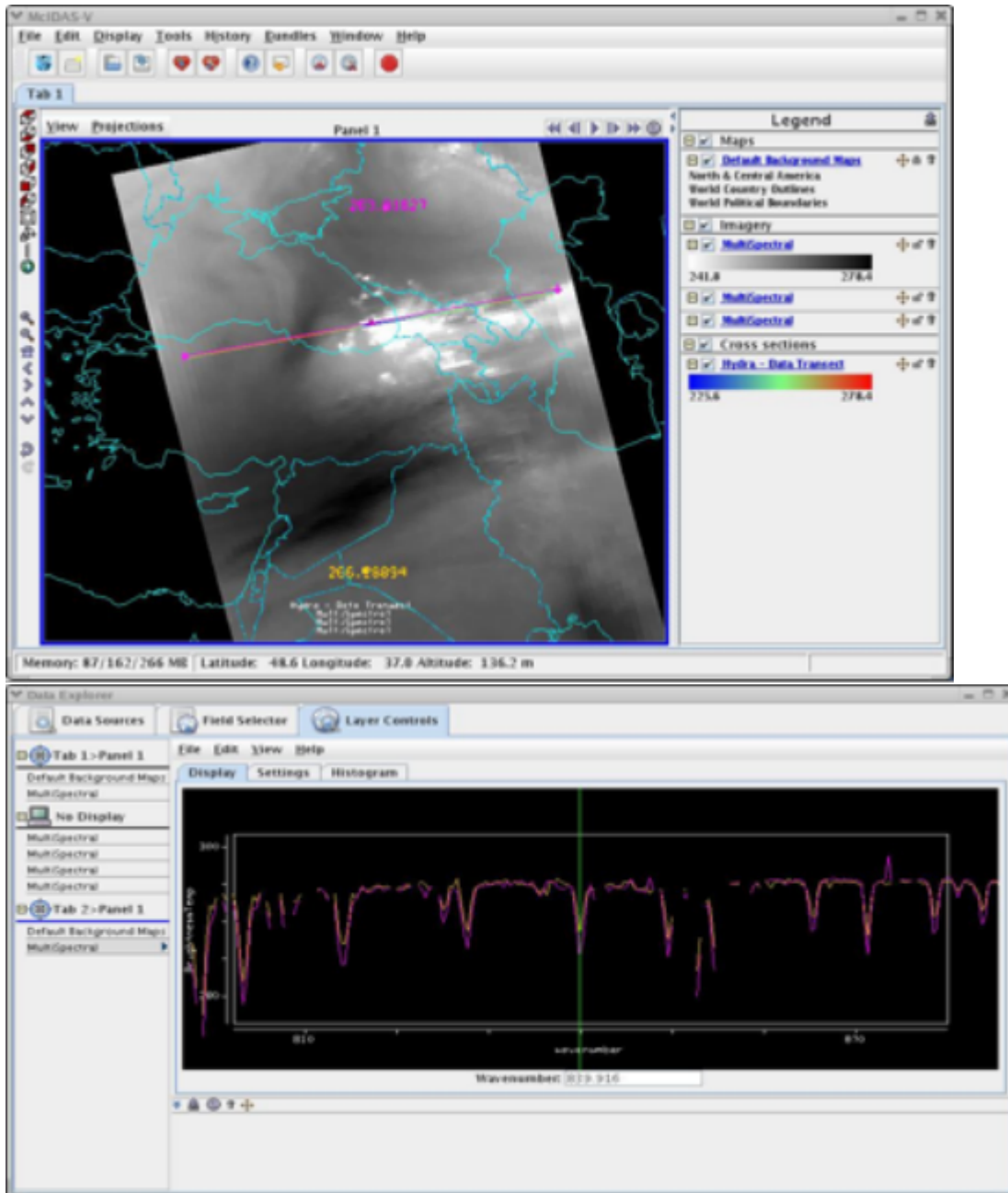
Figure 6: McIDAS-V spectra zoom, comparing two geographic locations. Vertical green line can be dragged to change wavenumber of displayed image.