BAMS Article

McIDAS at 50 Years

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Satellite observations;
Community;
Software

ABSTRACT: With the dramatic increase in meteorological observational datasets over the past half century, there is an essential need to organize, display, interact with, and generate meteorological products. This need is ever increasing as more observational datasets have become available, especially from satellites. During the 1970s, several projects began developing interactive processing software systems. One of these projects was the Man computer Interactive Data Access System (McIDAS). Today, McIDAS is over 50 years old, has seen five generations of development, and is ever evolving onto the latest computer technology. As an extensible system, McIDAS is employed in a wide set of applications across meteorology, including weather forecasting, atmospheric science research, and education. Over these five decades, McIDAS has been instrumental in facilitating advancements in meteorology such as the development of derived atmospheric motion vectors and unique meteorological displays. Contributions McIDAS has made to meteorology and remote sensing are illustrated via examples from NOAA Operations, Spain's Agencia Estatal de Meteorologia (AEMET), NASA Langley Research Center (LaRC), and the College of DuPage. McIDAS is also used in special weather forecasting situations at NOAA, NASA, and the U.S. Antarctic Program, as well as at the National Transportation Safety Board (NTSB) for aviation accident investigations. McIDAS continues to visualize imagery from the latest meteorological satellites while utilizing available emerging computer technologies. Beyond these ongoing transformations, McIDAS will maintain the use of extensible data readers that facilitate consistent interactive visualization and analysis capabilities, leveraging the strengths of McIDAS in satellite display and analysis.

SIGNIFICANCE STATEMENT: The need to access, organize, and visualize meteorological data is at the bedrock of our atmospheric science discipline. The advent of modern computing facilitates means to accomplish these requirements effectively. Here, we showcase one of the leading and long running interactive processing systems in meteorology via its application in operational, research, and educational settings, as well as its significant contributions to meteorology product development and unique meteorological displays.

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1. Introduction

The interactive processing in atmospheric science began alongside the development of the computer and as weather satellite observations became a viable tool in the early 1970s. As a result, many weather software programs were developed to organize, analyze, and display meteorological data, including Weather Processor (WXP), Joint Environmental Toolkit (JET), Mark IV-B Meteorological Data Station (MDS), and Display 2-Dimensions (D2D)—later known as AWIPS (see appendix C for a list of all acronyms). Among the earliest systems still in use today is the Man computer Interactive Data Access System (McIDAS). Constructed at the Space Science and Engineering Center (SSEC) at the University of Wisconsin–Madison, the acronym was selected by Professor Verner E. Suomi, the first principal investigator of the McIDAS project, with specific intention. The lowercase "*c*" implies that while the computer is needed, it is not as important as the other elements like the user, the interactivity, and the access to data. McIDAS is not only still in use today but was the first software to implement features like animated satellite loops, derived products like atmospheric motion vectors (AMVs), and was the first real-time software used in broadcast meteorology (Lazzara et al. 1999).

McIDAS has found a niche working with observational datasets and data fusion. Its greatest strength is in its ability to work with satellite data in its native format and in an efficient manner. McIDAS allows the user to navigate, remap, reproject, color enhance, and mathematically manipulate the imagery while maintaining the scientific integrity of the data. It does so while utilizing the available computing resources of the time, always with an eye on efficiency. For instance, creating a simple satellite file format known as the area format allowed McIDAS to make calculations across large volumes of data, leading to AMVs being calculated quickly and efficiently. Combined with its support of a long history of weather satellites, including entire constellations of polar- or low-Earth-orbiting (LEO) and geostationary (GEO) platforms, the ability to overlay weather observations, maps, graphics, contours, model output, and more has uniquely led to the longevity of McIDAS in the community (Lazzara et al. 1999).

2. A brief history of McIDAS

The McIDAS project has seen five marked generations over the past 50 years, often evolving with scientific computing growth. The birth date of McIDAS has been roughly determined to be 12 October 1973, with the first applied use of the system (Lazzara et al. 1999). The first public display of McIDAS was presented at the AMS Annual Meeting in January 1977. The video titled "Processing and Display of Satellite and Conventional Meteorological Data for the Classroom" (Atmospheric, Oceanic, and Space Science Library 1977) shows contours being plotted over a map of the United States, as well as maps being displayed over satellite imagery (Whittaker 1977), which must have seemed very futuristic in 1977.

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a. Pre-McIDAS ("WINDCO" 1971–72). The precursor to McIDAS began as a very specific application of geostationary satellite data to see if satellite observations could be used to generate what were called cloud drift winds, today known as AMVs. The first successful system to do so was named WINDCO. This system utilized a combination of computer hardware and software to determine the geographical location of the clouds and to calculate the winds from a time sequence of satellite observations. This era laid the foundation for a very powerful feature for which McIDAS has been known, the ability to effectively navigate satellite imagery (Phillips and Smith 1973). Although it seems simple now, navigating the satellite accurately allowed scientists of the time to calculate the AMVs and, in turn, led to the ability to accurately plot maps and data on satellite imagery.

b. McIDAS first generation (1973–78). Professor Suomi was encouraged to build an integrated system after demonstrating WINDCO to NASA, NSF, and Department of Defense (DoD) on 12 April 1972. The first integrated system demonstrated data fusion with satellite imagery and the AMVs from WINDCO but also conventional surface observations, NWS radar data, and the ability to navigate and overlay maps on the display. It was used operationally at the local public television station, WHA-TV, Madison, Wisconsin, and was the first interactive meteorological processing system used on television. The first remote terminal was installed at the University of Wisconsin–Milwaukee and employed in their meteorology program. The first system created by SSEC was exported to the U.S. Air Force Cambridge Research Laboratory in 1975 (Lazzara et al. 1999).

c. McIDAS second generation (1978–83). With the development of the new Visible Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) instrument on U.S. geostationary satellites (Schmit et al. 2026), a second generation of McIDAS was required to facilitate new applications. It maintained the ingest and usage of all prior datasets and added NWP and a new satellite series, the POES series of satellites from the Television and Infrared Observation Satellite (TIROS), and NOAA satellite series. Being an early data visualization system, McIDAS was used for many other applications, including visualizing imagery from Landsat and planetary missions, such as Mariner and Voyager (see appendix A for other names for McIDAS, and appendix B for other nonmeteorological usage).

d. McIDAS third generation (1983–96). Interest in McIDAS grew across the community in the late 1970s and into the early 1980s. It led to McIDAS on newer computer systems, especially mainframe computing platforms, the International Business Machines (IBM) mainframe being the mainstay centralized mainframe computing system for this era. If any technology was not available commercially, which was especially true for satellite ingestion capabilities, it was developed at SSEC. McIDAS usage experienced explosive growth during this era in operational organizations worldwide, university and educational settings, research environments, and in the private business sector as well, giving rise to an organized McIDAS Users' Group (MUG) to help assure software standards and provide support for members.

e. McIDAS fourth generation (1996–present). The advent of the McIDAS-X system, or McIDAS based on the UniX platform, ushers in the fourth generation, marked with an evolution back to a distributed system and the development of the Abstract Data Distribution Environment (ADDE) (Taylor et al. 1995). The explosive growth of the internet using Transmission Control Protocol/Internet protocol suite (TCP/IP) technology fueled this generation. Now, McIDAS returned as true client software, with it being server agnostic. McIDAS could

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now serve data to itself as both client and server, and it could access data on servers at remote locations anywhere on the internet.

f. McIDAS fifth generation (2009–present). The fifth generation of McIDAS is McIDAS-V, a Java-based client software system. While McIDAS-X and McIDAS-V both utilize ADDE, McIDAS-V is a departure from prior generations as it is a combination of several new software systems (Achtor et al. 2008): 1) the Integrated Data Viewer (IDV) from NSF Unidata, built upon 2) SSEC's Visualization for Algorithm Development (VisAD) software, with roots in McIDAS-4D (4 Dimension; Hibbard and Santek 1989) and Vis5D, and 3) Hyperspectral data viewer for Development of Research Applications (HYDRA; Rink et al. 2007). As a combination of the IDV (and thus VisAD) and HYDRA, McIDAS-V has expanded capabilities to work with other server systems, including Thematic Real-time Environmental Distributed Data Services (THREDDS), and with additional data formats, including the science community standards of netCDF and HDF (Hierarchical Data Format).

3. Operational use of McIDAS in NOAA operations (1980s–present)

McIDAS has been in use in NOAA Office of Satellite and Product Operations (OSPO) for product generation, satellite data distribution to the NWS, and specialized forecast and monitoring activities by NOAA NESDIS (Davenport 2018). Additionally, McIDAS was utilized directly by the NWS via the RAMSDIS or Regional and Mesoscale Meteorology (RAMM) Advanced Meteorological Satellite Demonstration and Interpretation System (Molenar et al. 2000). Before the adoption of the AWIPS system, RAMSDIS provided NWS with digital access to satellite observations. RAMSDIS was deployed across a range of environments within NOAA, including Weather Forecast Offices (WFO) across the country and National Centers such as Volcanic Ash Advisory Center (VAAC), Weather Prediction Center (WPC), etc.

a. Product generation. More than 50 applications were developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and NESDIS for creating satellite products used by forecasters and visualized in McIDAS. These include the advanced Dvorak technique (ADT; Olander and Velden 2007), automated biomass burning algorithm (ABBA; Prins et al. 1998), and cloud-top brightness temperature (CTBT; Gerlach 1980).

b. Satellite data distribution. Before the current GOES-R series geostationary satellites were operational, 20 SSEC-developed data ingestors (SDI; Santek et al. 2016) were installed at National Satellite Operations Facility (NSOF) to acquire real-time data for distribution to the NWS through the GOES Ingest NOAAPort Interface (GINI) broadcast service. After data acquisition, McIDAS was used to reproject and reformat the satellite imagery in near–real time. Although the operational workflow at the NWS has changed and AWIPS is no longer receiving McIDAS images directly through GINI, groups at NOAA, NASA, and worldwide are continuing to use McIDAS operationally.

c. Specialized forecasting and monitoring. At the NOAA Satellite Applications Branch (SAB), forecasters provide 24/7 operational support for five disaster mitigation desks: heavy precipitation, volcanic ash, fire/smoke/dust, marine pollution, and tropical cyclones. This is done at 10 workstations running McIDAS providing near-global coverage at multiple domain scales, each with 1800 frames of quickly and routinely loaded imagery (Davenport 2018). The forecasters perform data interrogation at the pixel level, manipulation, and value-added analysis for time-sensitive and rapidly evolving natural and human-caused hazards, such as volcanic eruptions, flash flooding, and fires.

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4. Operational use of McIDAS at Spain's National Meteorological Service, AEMET (1989–present)

Following several episodes of torrential rain due to cutoff lows along the Mediterranean coast, the Spanish government invested significantly in modernizing resources at the National Meteorological Institute (INM) [renamed Agencia Estatal de Meteorologia (AEMET) in 2010]. This included deploying a radar network and lightning detection units, as well as advancements in NWP and satellite reception and utilization. McIDAS covered the operational needs to organize, display, interact with, and generate products from all these meteorological sources at INM.

The introduction of McIDAS in 1989 marked a revolution. In regional offices, the transition shifted from radio facsimile, teletype, and manual plotting to the interactive display of satellite, observation, and NWP data on a common McIDAS interface. The system supported several McIDAS terminals at headquarters and one terminal at each regional center. A McIDAS ADDE client program was created to make Meteosat satellite imagery available to the Spanish radar network machines. This was primarily used for land echo suppression (Martinez and Aguado 1999) and subsequently used to develop local radar McIDAS ADDE datasets at every regional center (Aguado 2004).

Since 1997, AEMET has been the leading entity in a consortium of several national meteorological services—France, Sweden, and Austria—for the development of software for using the Meteosat Second Generation (MSG) data in nowcasting, known as the Nowcasting & Very Short Range Forecasting Satellite Application Facility (SAF), or NWCSAF, part of EUMETSAT's SAF network. Leveraging the experience gained from the radar ADDE development, McIDAS secondary servers for MSG data, and NWCSAF products were completed in the early 2000s, prior to the launch of MSG-1. Subsequent use of McIDAS in NWCSAF included a secondary server for MSG data from HRIT files (Fig. 1) and NWCSAF products from HDF-5 and McIDAS AREA files. Problems encountered postlaunch led to the creation of the EUMETCast dissemination system (Martinez et al. 2010). As a result, when the MSG program began to disseminate its images using EUMETCast, the infrastructure supporting both MSG and NWCSAF was fully operational on day 1. These MSG ADDE secondary servers were shared with SSEC and serve as the foundation for those still operational today.

During the 2010 EUMETSAT Conference in Córdoba, Spain, there was a presentation on the use of McIDAS-V with Infrared Atmospheric Sounding Interferometer (IASI) data. As AEMET began preparing for the Meteosat Third Generation (MTG) era, the HYDRA utility within McIDAS-V was used for the interactive visualization of hyperspectral data. Since McIDAS-V allowed the reading of IASI level 1 (L1) files from the EUMETSAT archive at that time, airmass and dust RGB images were generated using real IASI data (Martinez and Calbet 2013), demonstrating that L1 data from hyperspectral instruments could be used to directly generate images in McIDAS-V.

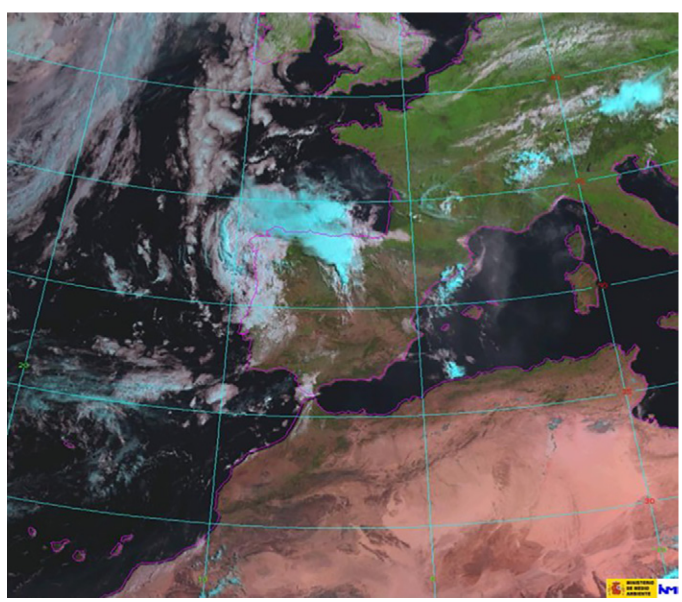

Fig. 1. One of the first MSG natural RGB images from 2003, created with a local McIDAS-X command to add in the INM logo for inclusion on the early INM website.

Since 2018, NWCSAF files have been written in the netCDF format following the climate and forecast (CF) convention. Consequently,

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these files can be used directly in McIDAS-V as an additional visualization tool, taking full advantage of the 4D data cube of the MTG era. L1 data from the Flexible Combined Imager (FCI) instrument onboard the MTG-I (imager) satellite can be visualized in McIDAS using any of the three ways: 1) the SSEC McIDAS FCI ADDE servers, 2) as netCDF files created by the NWCSAF level 1 Satellite Data (L1SD) product, or 3) the temporary FCI Small Disseminated (FSD) files generated during the creation of any NWCSAF FCI product. Additionally, FCI level 2 (L2) products from NWCSAF can be visualized in McIDAS-V. For the Infrared Sounder (IRS) instrument aboard the MTG-S (sounder) satellite, the NWCSAF is developing a software package, NWCSAF/GEO-S (GEO sounder), which will include an option to generate IRS L1 & L2 files compatible with McIDAS-V for 2D and 3D visualizations. Thus, McIDAS is poised to remain a useful tool in the coming years of the MTG era (Martinez 2025).

5. Research use of McIDAS at NASA Langley Research Center (1992–present)

Researchers at LaRC began using McIDAS-X in the mid-1990s for near-real-time and archived satellite and NWP data acquisition and processing. These data were initially used to generate cloud detection and micro-/macro-physical products (Fig. 2) that supported field campaign operations and science investigations for numerous NASA and Department of Energy Atmospheric Radiation Measurement (DOE ARM) field campaigns. Research aircraft locations and satellite overpass locations were overlaid with imagery within McIDAS to inform mission planners of weather conditions in the vicinity and of the aircraft's proximity to satellite orbits (Fig. 3). This capability is unique and extremely valuable to optimize flight tracks in real time and maximize science return from the campaigns. McIDAS is also being used within the NASA Clouds and the Earth's Radiant Energy System (CERES) project to acquire historical GEO imagery (Doelling et al. 2013) that are used to produce a long-term, integrated global climate data record for detecting decadal changes in cloud cover and Earth's radiation budget from the surface to the top of atmosphere. McIDAS satellite imagery and derived cloud product displays are used at LaRC to study aircraft contrails (Duda et al. 2001) and weather hazards such as aircraft icing (Smith et al. 2012) and severe convection (Bedka et al. 2018). Over the last three decades, many custom software packages were written for McIDAS at NASA LaRC, and feedback provided by McIDAS users at LaRC resulted in many software improvements.

NASA LaRC scientists were early adopters of McIDAS-V, with many active users. The McIDAS-V capability to display and interactively analyze and interrogate netCDF, HDF, McIDAS AREA, and a variety of other four-dimensional geophysical datasets with varying spatiotemporal resolution has been, and is currently, highly beneficial to improve LaRC data products and our understanding of weather and climate processes. Imagery and animations created within McIDAS-V are used in many presentations and publications (e.g., Bedka et al. 2010).

6. Educational and operational usage of McIDAS at the College of DuPage

The NSF Unidata program at UCAR has supported colleges and universities with data and software, including McIDAS, since 1989. A prime example of this is College of DuPage (COD), who have been McIDAS users since the early 1990s. Using McIDAS to generate satellite imagery, COD launched the weather.cod.edu website (Fig. 4) as one of the first sites to offer satellite images to the public, which was revolutionary at the time. Today, COD processes hundreds of sectors from all 16 channels of GOES imagery, including derived products and GOES Lightning Mapper (GLM) data, all produced with McIDAS from tiles sent across the Satellite Broadcast Network (SBN, also known as NOAAPort). Since full resolution sectors from SBN do not cover all of Canada, COD also uses a Unidata GOES Rebroadcast (GRB) feed to make full-disk images at full resolution, showing the format flexibility of McIDAS.

According to website statistics, the COD website averages 25 million hits on weekdays, and the satellite page comprises over 90% of that traffic. During severe weather outbreaks, this

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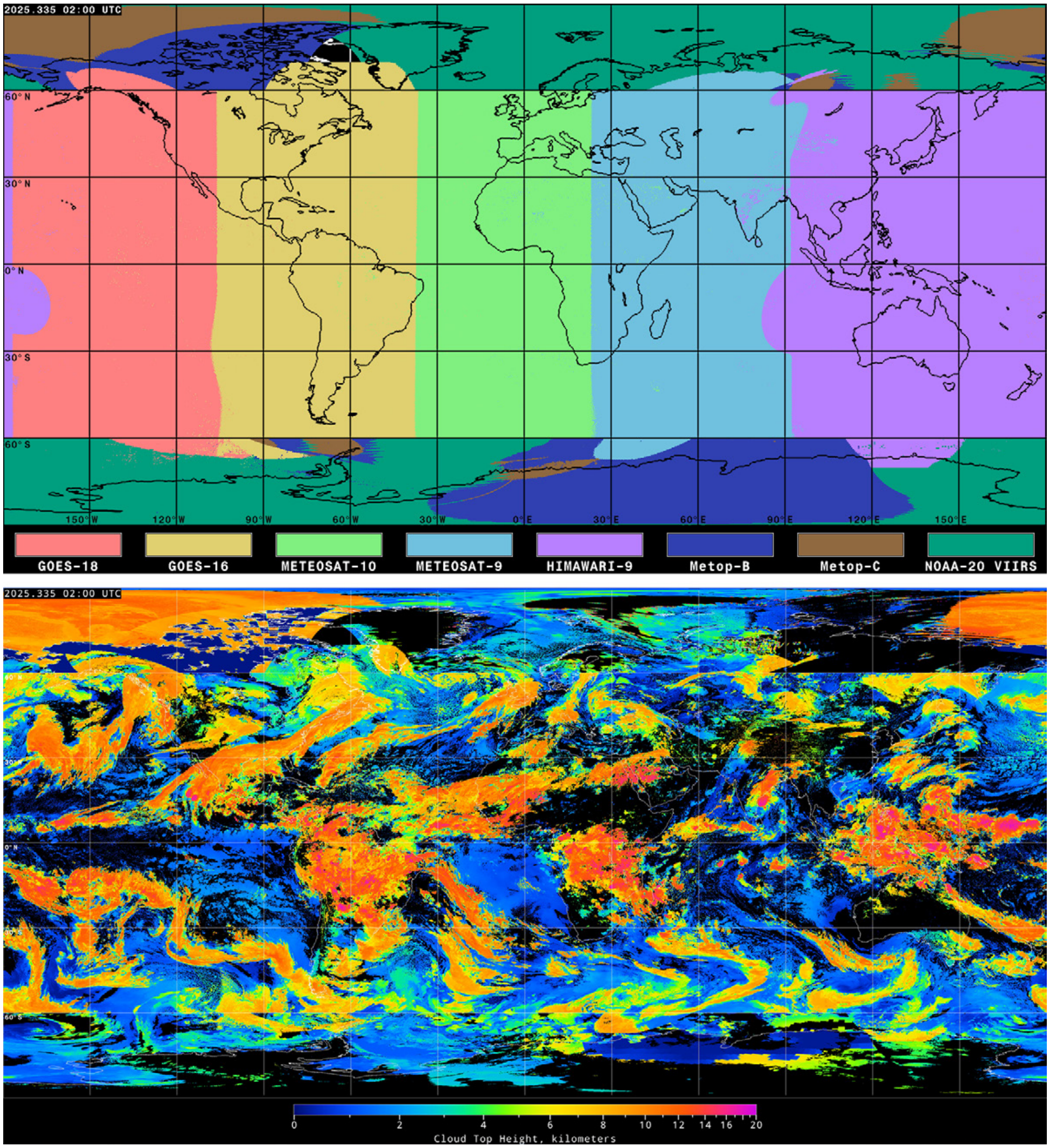

Fig. 2. NASA Langley Satellite Cloud and Radiation Property retrieval System Global Cloud Composite (bottom) cloud-top height and (top) satellite ID generated from GEO and LEO satellites, a product enabled by remote GEO data access and domain subsetting from the McIDAS-X ADDE server.

daily number can double, and during major hurricanes that impact the United States, that number triples. COD's McIDAS-processed images are used by both the U.S. military and the National Weather Service forecast and aviation weather offices, showing the value and quality of the images produced. Although the webpage's largest user is the National Weather Service (web site statistics, 2026), its primary intent is to teach students at COD and at a wide range of universities basic satellite interpretation, including jet stream patterns, cloud identification, and more. By the time graduating students reach junior and senior college-level programs, they are well prepared to handle advanced weather concepts, thanks in significant part to McIDAS.

7. Contributions of McIDAS to the atmospheric sciences

McIDAS has facilitated and contributed to the advances in atmospheric sciences and has broadened its impact across several areas of meteorology. With visualization of satellite imagery and then data fusion such as AMVs or DMWs, features of the original McIDAS still exist

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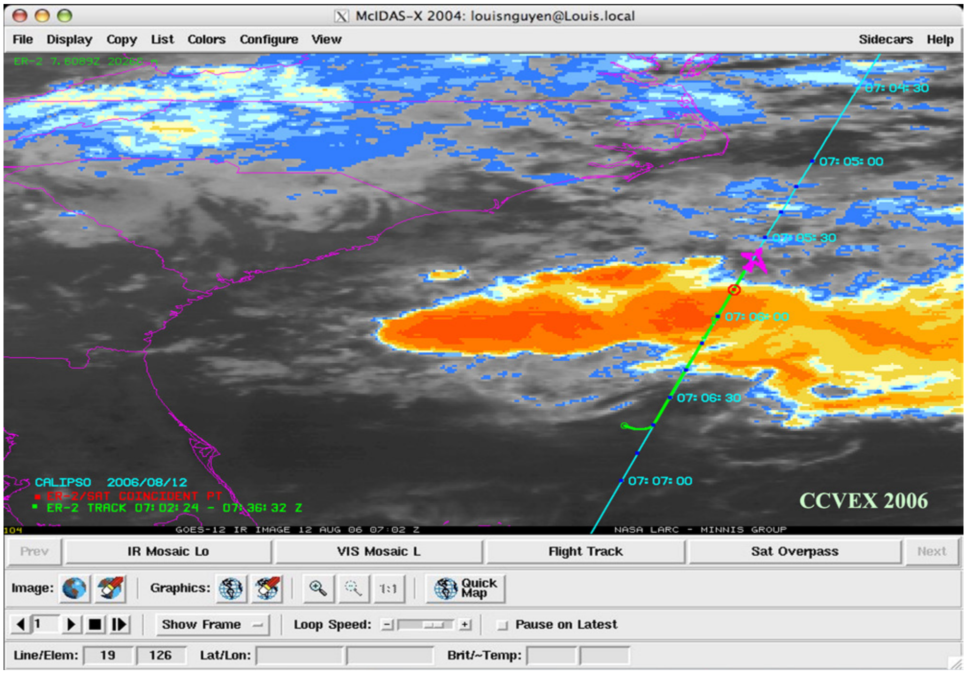

Fig. 3. An overlay of NASA ER-2 aircraft flight track (green), aircraft position (magenta icon), and *CALIPSO* satellite track (cyan) atop a color-enhanced *GOES-12* 10.7-μm infrared image during the 2006 NASA *CALIPSO–CloudSat* Validation Experiment, displayed in a McIDAS-X GUI.

in many satellite systems today. The processing tools within McIDAS enabled many unique products to be created from McIDAS, including composite satellite imagery. McIDAS development at SSEC has led to a data center and data archive that is one of the most complete in the meteorological world. McIDAS-V has given meteorologists the ability to view traditionally two-dimensional data in three dimensions. Below are brief descriptions of how McIDAS contributed to the development of these meteorological advances.

a. AMVs. From its inception, McIDAS has been intertwined with the advent of using cloud features and their tracked motions as a basis for generating satellite-measured winds. From a manual process beginning in the 1970s (Fig. 5; Whittaker 1977), a fully automated version

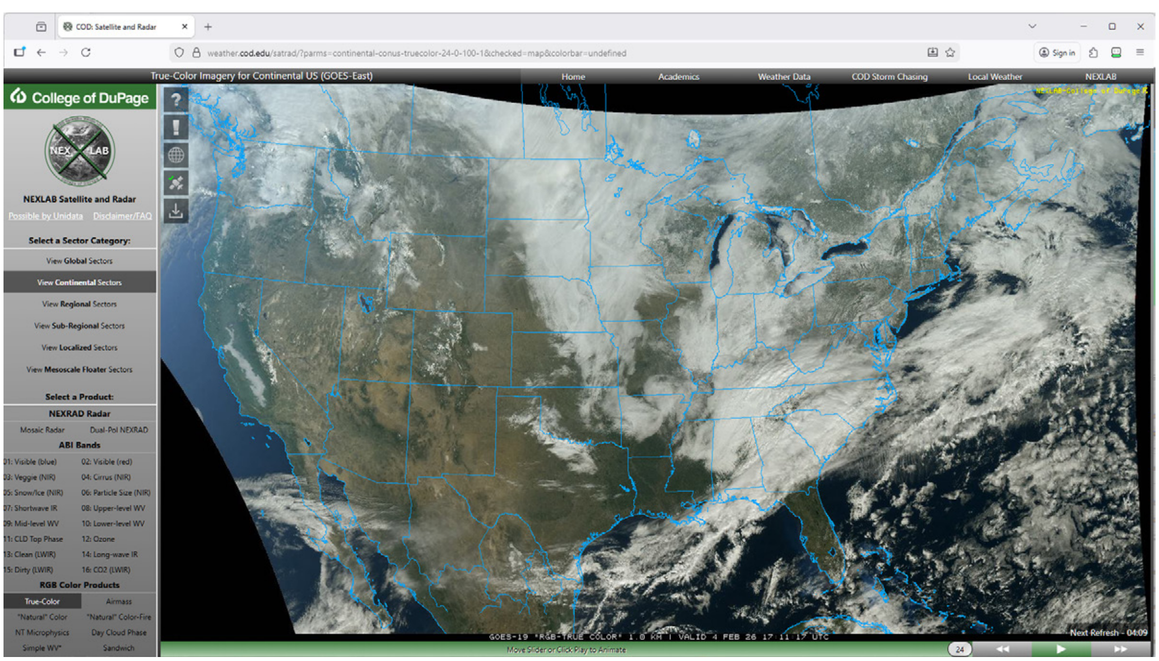

Fig. 4. The COD website, showing GOES East true color imagery created using McIDAS-X.

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was implemented in McIDAS in the 1990s for geostationary satellites (Nieman et al. 1997) and in the early 2000s for LEO satellites (Key et al. 2003). Many advances were made to the winds algorithm during the 2000s (Velden et al. 2005). McIDAS was not only the first to offer AMVs but also led to most current meteorological satellite systems offering AMVs as a standard product. The AMVs are critical for NWP, data assimilation, and improving forecast outcomes (Key et al. 2003; Santek 2010).

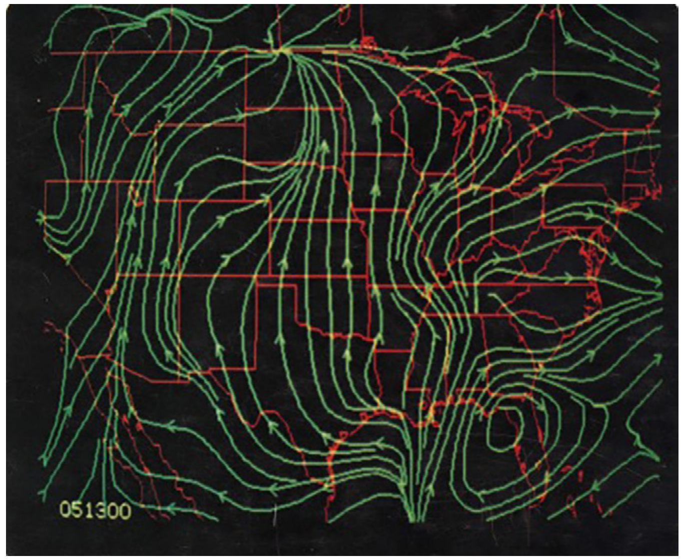

Fig. 5. AMVs plotted as streamlines in McIDAS-X in 1977 (Whittaker 1977).

b. Satellite composite imagery. Satellite composite imagery began at SSEC via two avenues: one from the Antarctic Meteorology Research Center (AMRC), now known as the Antarctic Meteorological Research and Data Center (AMRDC; Lazzara et al. 2025) with a focus on the polar regions and the other via the SSEC Satellite Data Services (SDS, historically known as the SSEC Data Center) with a focus on global composite imagery (Kohrs et al. 2013).

In 1992, the AMRC was established as a marriage of the McIDAS project and the U.S. automatic weather station (AWS) project. For over 30 years, AMRDC has focused on the unique generation of Antarctic satellite composite imagery with McIDAS (Fig. 6; Lazzara et al. 2003, 2011; Kohrs et al. 2013). The composites have been used for weather forecasting (A. Cayette 2017, personal communication), research investigations (Lazzara et al. 2014), and outreach, including extreme Antarctic weather events (e.g., Verezemskaya et al. 2017; Zou et al. 2023).

SSEC SDS currently uses a combination of core and user-written McIDAS code to create a number of specialized satellite products. One such product is a global image depicting local solar noon (Fig. 7), created daily by combining 24 h of geostationary satellite data using pixels from the red, green, and blue wavelengths of the visible spectrum (Miller et al. 2016). For another product, SDS employs a unique method to identify overshooting tops using a blend of visible and infrared data to create the "sandwich product" (Bedka et al. 2010; Setvák et al. 2013). Products created using these multispectral data have proven to be invaluable to forecasters and researchers. Generally used for severe weather conditions, the sandwich product can also be used to show the complex structure of an ash cloud from a volcanic eruption (Fig. 8).

c. Data recovery and rescue. McIDAS has been instrumental in rescuing and preserving historical satellite datasets in SDS. In the early 2000s, a major effort focused on recovering the Synchronous Meteorological Satellite (SMS-1 and SMS-2) and early *GOES-1* through *GOES-7* data archive (3 months of 1974, and 1978–96) from U-matic tapes. Early GOES variable (GVAR) data from *GOES-8* and *GOES-9* (1994–2004) were migrated from U-matic and 3590 tapes. Modified SDS desktop ingestors read the tapes, and the data were delivered to NCDC (now NCEI). McIDAS facilitated data quality control throughout this process (University of Wisconsin–Madison SSEC and NOAA OSPO 1974), and since 2022, McIDAS has been used to apply or improve navigation for these rescued datasets (Robaidek 2025). This work utilized

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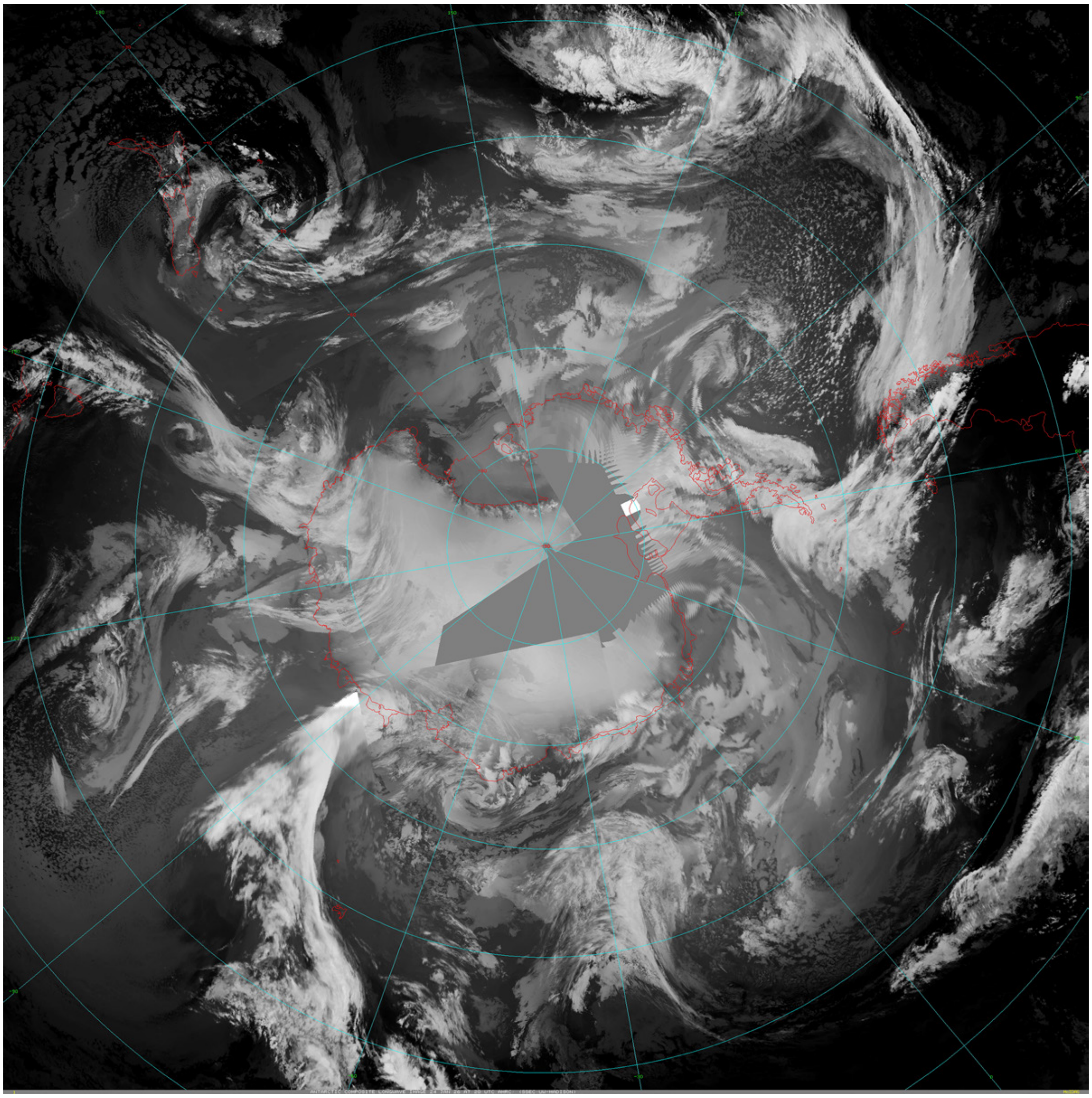

Fig. 6. An example of an Antarctic satellite composite that is produced in McIDAS-X with a combination of geostationary and polar-orbiting satellite imagery.

legacy McIDAS routines from the 1980s to rescue some of the oldest geostationary weather satellite data, including digitized Applications Technology Satellites (ATS-1 and ATS-3) data from 1966 to 1974, and daily SMS and GOES images from 1975 to 1978, all viewable with McIDAS (Fig. 9). A notable example of this capability is the recovery and navigation of SMS-2 imagery from 10 November 1975 (Fig. 10), which captured the weather conditions over Lake Superior on the evening the SS *Edmund Fitzgerald* sank. This scanned image was navigated and enhanced using McIDAS, demonstrating the system's ability to bring scientific value to historically significant archived imagery. Future efforts will use McIDAS to apply rudimentary calibration to scanned images where calibration chips or wedges are present, further enhancing the scientific value of these early Earth observations.

d. Three-dimensional views of traditionally two-dimensional data. McIDAS-V, which has its heritage in Vis5D and VisAD, provides robust 3D visualization capabilities through its mathematical framework and interactive displays, enabling the creation of vertical cross sections, isosurfaces, and volumetric renderings of meteorological data (Fig. 11). These 3D display types facilitate analysis by allowing users to simultaneously examine both the horizontal and vertical, improving interpretation of complex phenomena such as storm

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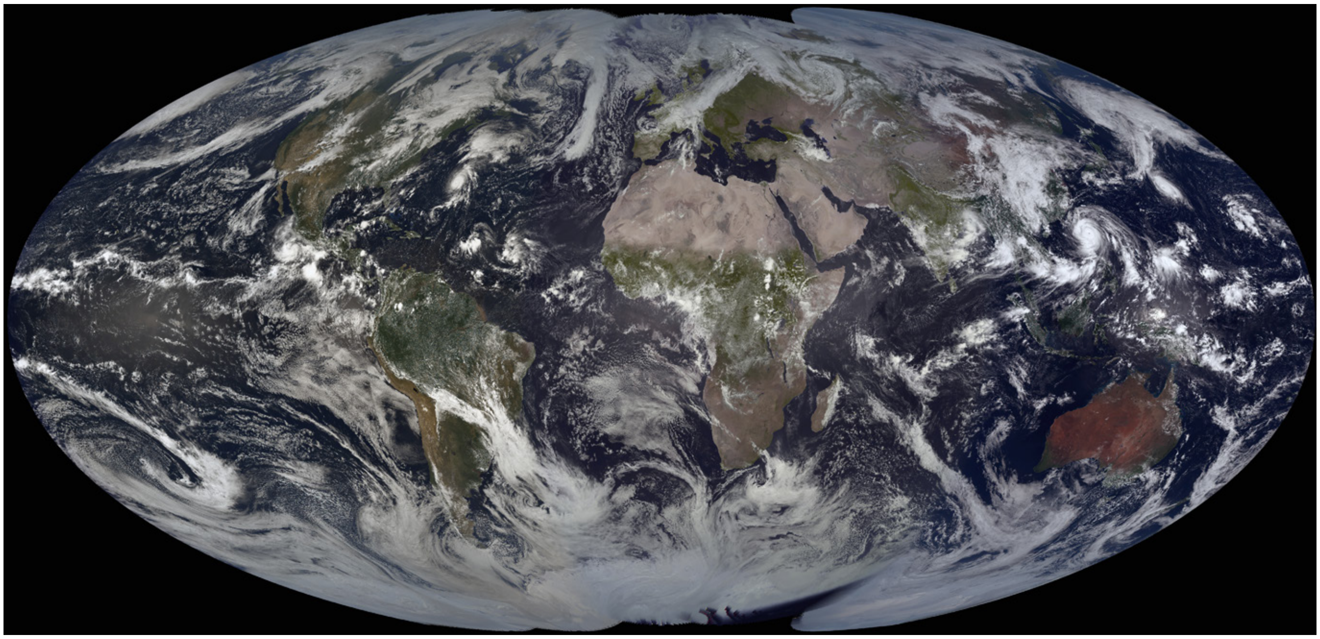

Fig. 7. **A composite of GOES, Himawari, and Meteosat satellites utilizing visible pixels from local solar noon on 22 Sep 2025, created with McIDAS-X.**

structure. By supporting interactive exploration across multiple vertical levels, McIDAS-V enhances both visualization and scientific understanding of 3D datasets in three spatial dimensions and with time. An early example of McIDAS-V used in research is the SSEC/CIMSS convective weather project (Bedka et al. 2010), where scientists viewing the contours from above were able to interactively and immediately rotate the data view to the side and were able to easily visualize the overshooting tops from the side (Fig. 12).

8. McIDAS in the community

McIDAS can be found in a variety of settings, especially as a tool for creating content for education and NOAA satellite viewers and blogs, for example,

- CIMSS Satellite Blog—https://cimss.ssec.wisc.edu/satellite-blog/;
- College of DuPage NEXLAB Satellite & Radar—https://weather.cod.edu/satrad/;
- NOAA/NESDIS/STAR GOES Imagery Viewer—https://www.star.nesdis.noaa.gov/goes/
- (M. Jochum and NOAA 2026, personal communication);
- NOAA Science on a Sphere (SOS)—https://sos.noaa.gov/; and
- RealEarth™—https://realearth.ssec.wisc.edu/.

In the meteorological community, the research and operational forecasting arenas have all employed McIDAS over the last 50 years. Below is the list of these McIDAS Users' Group member organizations from the last three generations of McIDAS, past and present.

a. Research and operational forecasting in education, government, and military.

- United States—AMRDC, AWC, Cape Canaveral Space Force Station, CIMSS, CIRA, Columbia Scientific Balloon Facility, Federal Aviation Administration, GSFC, Johnson Space Center, Kennedy Space Center, Lawrence Livermore National Laboratory, NASA Marshall Space Flight Center, NASA LaRC, NCAR, NCEP Central Operations, NHC, NOAA CLASS, NOAA OSPO, NOAA STAR, National Laboratory of the Rockies, NSF Unidata, NSSL, NTSB,

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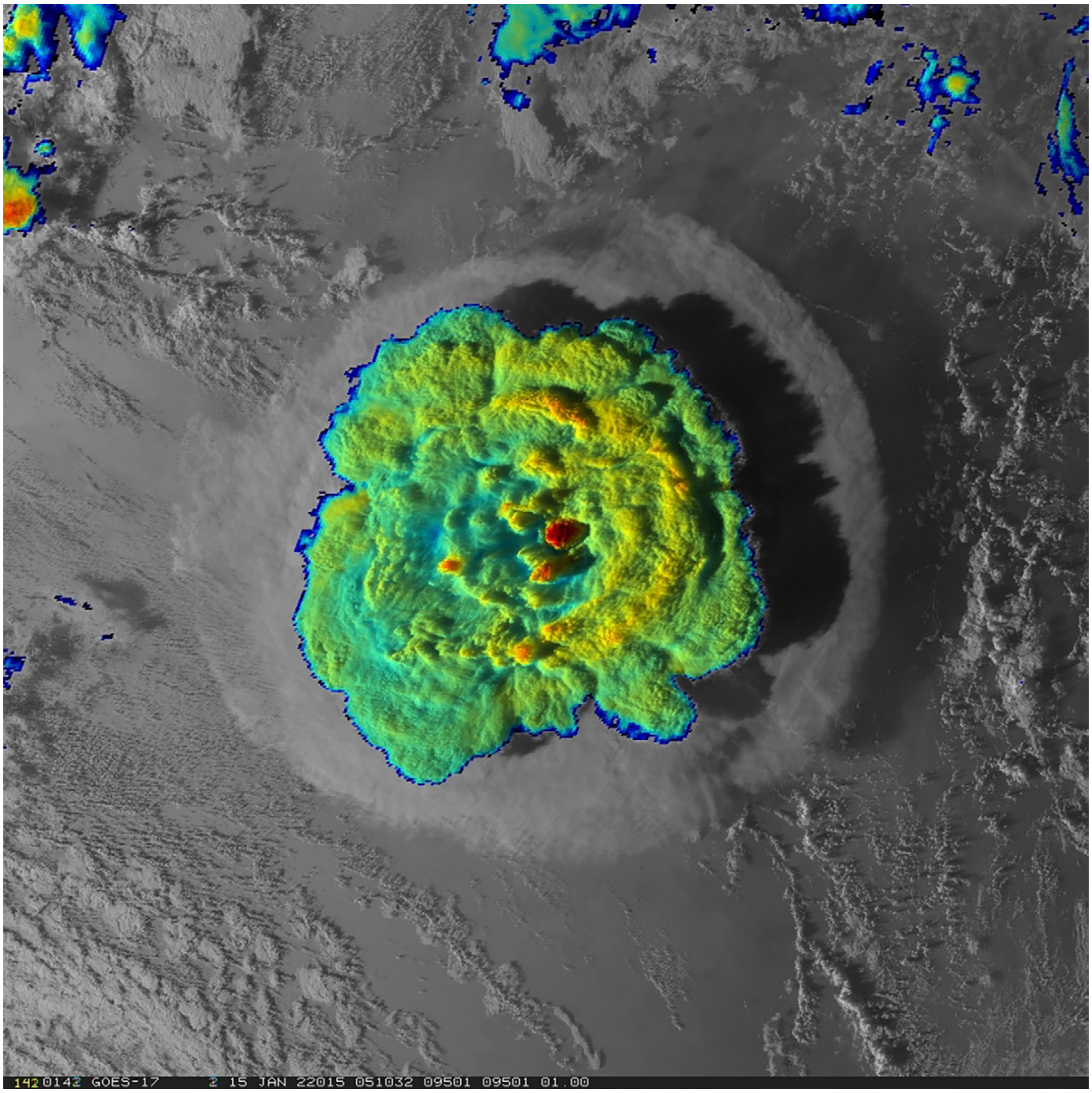

Fig. 8. ***GOES-17*** **sandwich product from 0510:32 UTC 15 Jan 2022, showing the Hunga Tonga–Hunga Haʻapai eruption of a submarine volcano in the Tongan archipelago in the southern Pacific Ocean displayed in McIDAS-X.**

NWS, Schriever Air Force Base, SPC, SSEC, Vandenberg Space Force Base, White Sands Missile Range.

- Others outside of the United States—Argentina, Australia, Canada, China, ECMWF, EUMETSAT, Fiji, France, Germany, Greece, Hong Kong, India, Indonesia, Italy, Japan, Kwajalein Atoll, Korea, Malaysia, Mexico, Mongolia, Spain, Taiwan, Turkey, United Arab Emirates, United Kingdom.

b. Research and operational forecasting in the private sector.

- 3Tier, AccuWeather, Aerojet, Aeromet, Aerospace, Boeing, Clean Power, Clear Ag, Climatological Consulting Corporation, Digital Cyclone, Data Transmission Network (DTN), Energia Logistics, Engineering and Science Corporation (ENSCO), FedEx, Firnspiegel, Green Power Labs, Harris, Honeywell, IBM, Impact Wx, Iteris, Lockheed Martin, Mars Snackfood, Northrop Grumman, Raytheon, Solargis, StormGeo, Universal Weather, Visidyne, Vision Tech, Weather Decision Technologies (WDT), Weather Central, the Weather Channel, Weather Extreme, Weathernews, WTVT Tampa.

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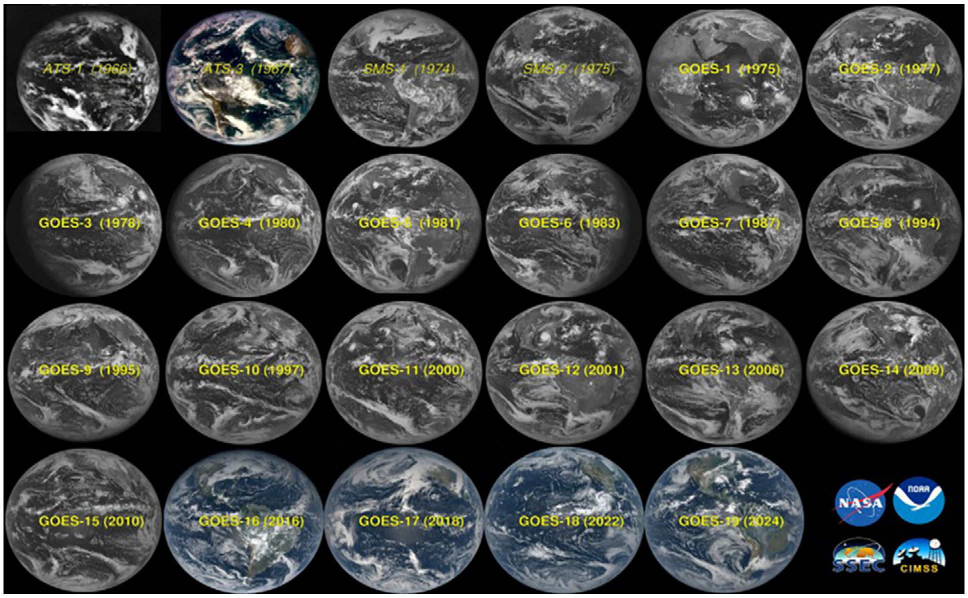

Fig. 9. McIDAS-X images displaying satellite imagery from 1966 (ATS-1) to the present (*GOES-19*) (courtesy of Tim Schmit).

9. Conclusions and the future

For over 50 years, McIDAS has been a noteworthy contributor to the meteorological community. The development and evolution of many meteorological interactive processes and products have been possible because of the developments made within McIDAS. McIDAS was one of the first systems to organize, interact with, and display meteorological datasets, and McIDAS continues to add new data sources and data types to its repertoire. Data from new satellites like MTG and Metop-SG are now available in McIDAS and are included in SSEC's composite imagery, and data from NOAA's Geostationary Extended Observations (GeoXO) satellite will be added as the 2032 launch date approaches. McIDAS also displays, overlays, and manipulates data from the operational, artificial intelligence (AI)-driven global weather prediction models now available from NOAA. As always, McIDAS continues to utilize the emerging technologies of today, such as cloud computing and the Python programming language. Case in point, Arctic satellite composites are now generated in real-time via NOAA's cloud framework and include the latest operational satellites servers written in Python instead of Fortran or C. The development of Python-based ADDE servers is poised to be a significant legacy that McIDAS provides to the community. McIDAS has been

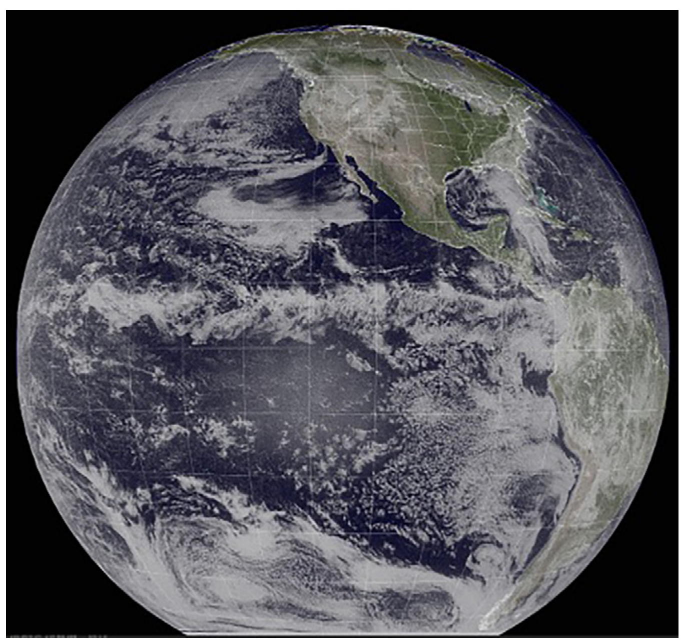

Fig. 10. SMS-2 satellite imagery from 1945 UTC 10 Nov 1975 showing weather conditions over the Western Hemisphere, including the Great Lakes region, during the sinking of the SS *Edmund Fitzgerald*. This image was recovered from scanned archives and navigated and enhanced using McIDAS legacy routines adapted for historical satellite data.

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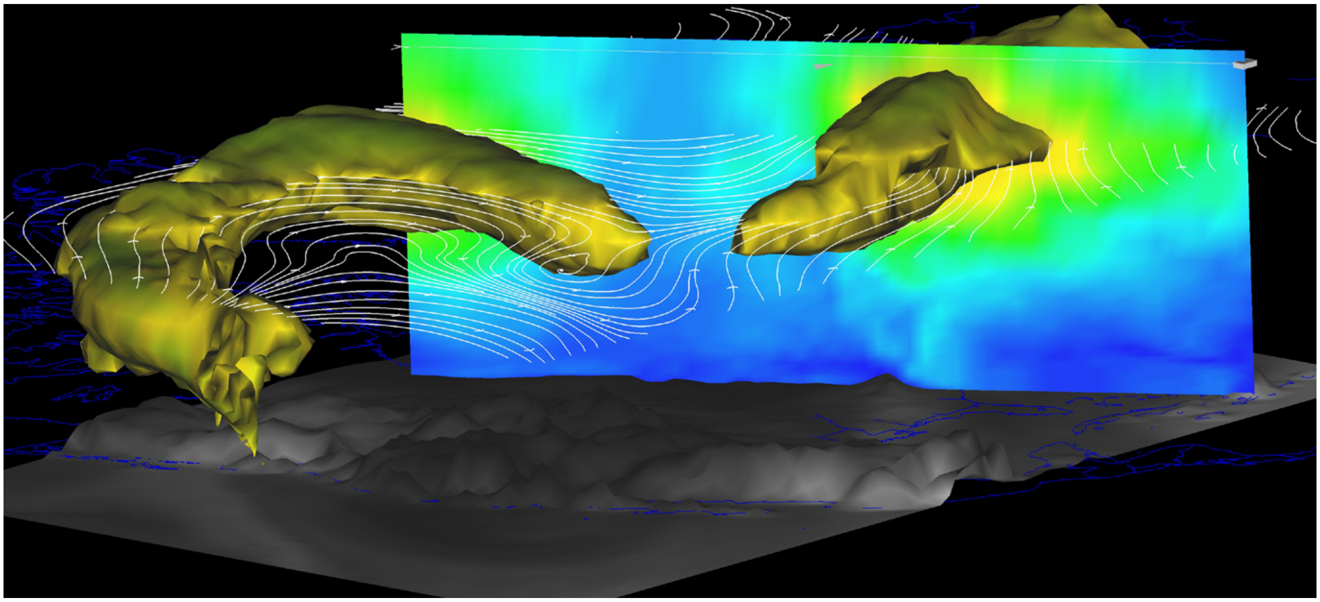

Fig. 11. A McIDAS-V display of GFS model data illustrating a vertical cross section of wind speed, upper-level streamlines, an isosurface of 50 m s^{-1} wind speed, and precipitable water drawn over the topography of North America.

historically used in the background of Unix environments with shell scripting but now also includes a Python package that can be used to run McIDAS commands in a Python environment. Future development is focusing on writing imagery data files in a machine learning format, such as Zarr. Much like the McIDAS Area format of the 1970s, this machine learning format will provide an efficient way to store and stream massive datasets that are now too large to fit into local memory. With these developments, McIDAS will be able to access data from multiple decades and process it in a machine learning environment. Another possibility for future development is adding an AI interpretation layer to McIDAS which could allow McIDAS to not only display data but also to explain the imagery to researchers, to students or even to the disabled, increasing the audience of the McIDAS world. Beyond these ongoing transformations, McIDAS will maintain the use of extensible data readers that facilitate consistent interactive visualization and analysis capabilities. Operational, research, and educational groups at places like NOAA, NASA, AEMET, and the College of DuPage will continue to leverage the strengths of McIDAS in satellite display and analysis. And while data and technology have been important in facilitating McIDAS, it is the people, the meteorologists, the students, and the computer scientists, who have been the most crucial factor in these past 50 years. That will remain the case for the next 50 years, as McIDAS is as much about its user community as it is about the software itself.

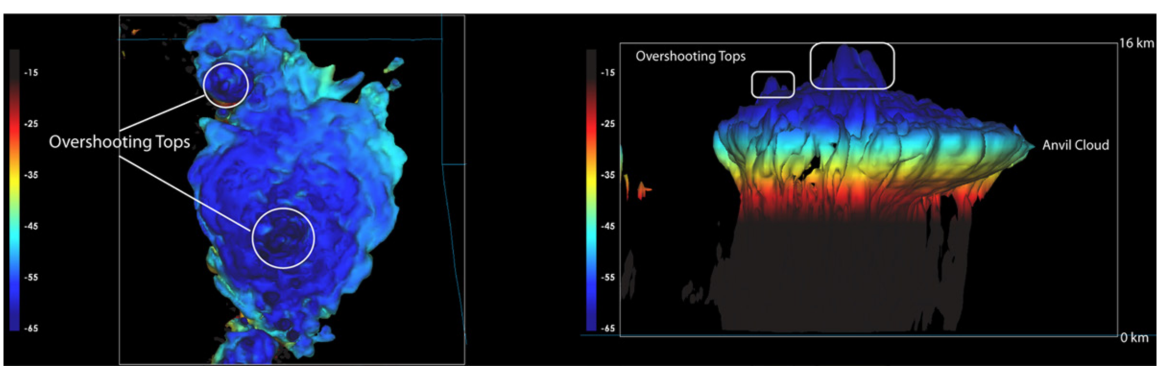

Fig. 12. A McIDAS-V rendering of the WRF cloud water isosurface colored by the WRF 3D temperature field as viewed from above and after being interactively rotated to the side.

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Acknowledgments. The McIDAS software has developed over the past five decades with input and support from many, including but not limited to, NSF, NOAA, NASA, DoD, and the McIDAS Users' Group membership. Their support and contributions have been invaluable in the maturity of the project. Thanks to all past and present members of the McIDAS team at Space Science and Engineering Center at the University of Wisconsin–Madison for their efforts on the McIDAS project. It is people, the end users, and project team that have made the difference! The authors thank the support of the National Science Foundation Grants 1951603 and 230162. Thanks also to those who have reviewed this document, whose comments and suggestions improved this manuscript. This manuscript is dedicated to the thousands of users of McIDAS worldwide, as well as the past and present members of the McIDAS Users' Group for their tireless efforts in support of the McIDAS project.

Data availability statement. McIDAS-X software is available via membership with the McIDAS Users' Group (https://www.ssec.wisc.edu/mcidas/). McIDAS-V software is available free of charge from the McIDAS-V Download Page (https://www.ssec.wisc.edu/mcidas/software/v/download/). Real-time and archive weather satellite data are available from the Satellite Data Services group at the University of Wisconsin–Madison Space Science and Engineering Center (https://www.ssec.wisc.edu/datacenter/). Surface station observations and Antarctic composite infrared satellite imagery data are available at Antarctic Meteorological Research and Data Center (AMRDC) (https://amrdcdata.ssec.wisc.edu/).

APPENDIX A
Named Systems

When the original McIDAS systems began to be installed at various locations, it was encouraged to give the systems unique names, despite them all being McIDAS systems. One of the first was Centralized Storm Information System (CSIS) at National Severe Storms Forecast Center (NSSFC) (Ostby 1992). The installation of the first system at NOAA was VISSR Image Registration and Gridding System (VIRGS), with the follow-up system named VAS Data Utilization Center (VDUC). The system installed to support NASA's Space Shuttle efforts was named Meteorological Information Data Display System (MIDDS). The Cooperative Institute for Research in the Atmosphere (CIRA) named their deployment of McIDAS to NWS offices around the United States as Regional and Mesoscale Meteorology (RAMM) Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS; Molenar et al. 2000). It was not documented, but the initial General Meteorology Package (GEMPAK)/NAWIPS had elements of McIDAS included to enable it to work with satellite imagery, illustrating one of the strengths of the McIDAS system.

APPENDIX B
McIDAS Trivia

The evolution of McIDAS over time includes some interesting and often little-known facts and trivia:

- The precursor system to McIDAS, WINDCO, was an idea of Professor V. E. Suomi's after he and Professor Bob Parent launched the first geostationary spin-scan satellite observations from the ATS satellite. Inspired by the development of instant replay in American football, Suomi realized he could utilize the newly navigated satellite observations from geostationary orbit at known times to calculate atmospheric motions of clouds features.
- The first user's guide of McIDAS commands was written on a Rolodex! This Rolodex still exists and is archived at the Atmospheric, Oceanic, and Space Sciences library at the University of Wisconsin–Madison. All commands were just two letters. For users of the current modern day McIDAS, one can trace back the lineage of some programs that have been utilized for over 50 years, as several two-letter commands are still in use today.

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- Second Generation McIDAS distributed computers all had three-character names such as Mom and Dad being more "central" systems and names like Abe, Ken, Liz, and Sue for the remote connected systems.
- The second generation of McIDAS was used for several nonmeteorological uses, including the visualization of X-ray scans, imagery of crystal structures, biological protein scans, and applications in planetary meteorology.
- During the 1990s, a stand-alone program—not built by the McIDAS group—called xloadimage, was able to read and display McIDAS Area formatted files. This, along with the GOES archive at NCEI (then NCDC) hosting the data in the Area format, ushered in the acceptance of McIDAS Area format as a standard data format in the meteorological community.
- Satellite ingest was an integrated part of the McIDAS mainframe system, later evolving into the SSEC Desktop Ingestor (SDI) PCI card system, then into the full SDI-104 ingest appliance, and to the current SDI GRB Appliance, now an integrated commercial off the shelf (COTS) server system.

APPENDIX C

Acronyms

ABBA	Automated biomass burning algorithm
ADDE	Abstract Data Distribution Environment
ADT	Advanced Dvorak technique
AEMET	Agencia Estatal de Meteorologia
AI	Artificial intelligence
AMS	American Meteorological Society
AMRC	Antarctic Meteorological Research Center (now AMRDC)
AMRDC	Antarctic Meteorological Research and Data Center
AMV	Atmospheric motion vectors
ATS	Applications Technology Satellite
AWC	Aviation Weather Center
AWIPS	Advanced Weather Interactive Processing System
AWS	Automatic weather station
CALIPSO	*Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations*
CF	Climate and Forecast
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere
CLASS	Comprehensive Large Array-data Stewardship System
COD	College of DuPage
COTS	Commercial off the shelf
CSIS	Centralized Storm Information System
CTBT	Cloud-top brightness temperature
D2D	Display 2-Dimensions
DMV	Derived Motion Vectors
DoD	Department of Defense
DOE ARM	Department of Energy Atmospheric Radiation Measurement
DTN	Data Transmission Network
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSCO	Engineering and Science Corporation
EUMETcast	European Organization for the Exploitation of Meteorological Cast
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FCI	Flexible Combined Imager
FSD	FCI Small Disseminated

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GEMPAK	General Meteorological Package
GEO	Geostationary Earth Orbiting satellite
GeoXO	Geostationary Extended Observations
GFS	Global Forecast System
GINI	GOES Ingest NOAAPort Interface
GLM	GOES Lightning Mapper
GOES	Geostationary Operational Environmental Satellite
GRB	GOES Rebroadcast
GSFC	Goddard Spaceflight Center
HDF	Hierarchical Data Format
HRIT	High Rate Information Transmission
HYDRA	Hyperspectral viewer for Development of Research Applications
IASI	Infrared Atmospheric Sounding Interferometer
IRS	Infrared Sounder
IBM	International Business Machines
JET	Joint Environmental Toolkit
L1	Level 1
L1SD	Level 1 Satellite Data
L2	Level 2
LaRC	NASA Langley Research Center
LEO	Low-Earth-orbiting satellite
McIDAS	Man computer Interactive Data Access System
MDS	Mark IV B Meteorological Data Station
MIDDS	Meteorological Information Data Display System
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
MUG	McIDAS Users' Group
NASA	National Aeronautics and Space Administration
NAWIPS	NCEP Advanced Weather Interactive Processing System
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEI	National Center for Environmental Information
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
netCDF	network Common Data Format
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NTSB	National Transportation Safety Board
NWCSAF	Nowcasting & Very Short Range Forecasting Satellite Application Facility
NWS	National Weather Service
OSPO	Office of Satellite and Product Operations
POES	Polar Operational Environmental Satellite
RAMM	Regional and Mesoscale Meteorology
RAMSDIS	Regional and Mesoscale Meteorology (RAMM) Advanced Meteorological Satellite Demonstration and Interpretation System
SAF	Satellite Application Facility
SBN	Satellite Broadcast Network (SBN, a.k.a. NOAAPort)

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SDI	SSEC Desktop Ingestor
SMS	Synchronous Meteorological Satellite
SOS	Science on a Sphere
SPC	Storm Prediction Center
SSEC	Space Science and Engineering Center
STAR	Center for Satellite Applications and Research
TCP/IP	Transmission Control Protocol/Internet protocol suite
TIROS	Television and Infrared Observing Satellite
THREDDS	Thematic Real-time Environmental Distributed Data Services
U.S.	United States
VAAC	Volcanic Ash Advisory Center
VAS	VISSR Atmospheric Sounder
VDUC	VAS Data Utilization Center
VIRGS	VISSR Image Registration and Gridding System
VisAD	Visualization for Algorithm Development
VISSR	Visible Infrared Spin Scan Radiometer
WDT	Weather Decision Technologies
WFO	Weather Forecast Office
WPC	Weather Prediction Center
WRF	Weather Research and Forecasting Model
WXP	Weather Processor

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