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Global Satellite Images for Aviation Operations

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1. Introduction

Flight planning and flight following dispatch operations require information on potential flight hazards. Hazards such as thunderstorms, turbulence, icing, fog, volcanic ash, etc. are potential problems which are not always forecast adequately by numerical models. Satellite images are used to monitor the weather conditions causing existing flight hazards, as well as being used to identify the development of new hazards. Geostationary weather satellite data are available around the world from the US (GOES-east and GOES-west), Japan (MTSAT), China (FY-2C, D, and E), and the European EUMETSAT (Meteosat and Meteosat Second Generation (MSG)). While individual satellite images for specific locations are easily available from web sites or in digital form, global aviation flights frequently pass from one satellite area of coverage to another. Satellite image products derived from a mosaic of satellite images are generally required for global aviation interests. In response to these requirements, some aviation oriented organizations have generated global mosaics of satellite images such as the Aviation Weather Center web site at http://aviationweather.gov/obs/sat/intl/. However, the existing global mosaics are generally available only for infrared images. Image products such as Water Vapor, Visible, Nighttime Fog, Volcanic Ash, Thunderstorm Detection, etc. have been developed by a number of satellite producers, but are generally available only over a limited area of the globe. The intent of this effort has been to develop an operational processing system that would make these other satellite products available for the entire globe.

The initial product suite has been an infrared product, a day/night visible/fog product, a thunderstorm detection product, a thunderstorm top height product, a water vapor product, and a volcanic ash product at a 4 km, 30 minute resolution for the globe, along with 1-2 km, 15 minute resolution regional products over the US and Europe. Two versions of the product suite are running. The version running at Embry-Riddle Aeronautical University (ERAU) uses only publically available digital satellite products. The biggest problem with the publically available satellite products is the distribution restrictions placed on the EUMETSAT data, which limits MSG and Meteosat Indian Ocean data to only 6 hours intervals. The Chinese satellite data can be used for coverage of the Asia regions through the Middle East with 30 minute coverage, but European and African regions are limited to 6 hourly intervals. The second version of the product suite is running at Telvent which has full access to the EUMETSAT data, and will provide the entire product suite to its commercial subscribers.

2. Data Sets

The input geostationary satellite data comes from the GOES-east and west, the Japanese MTSAT, the Chinese FY-2D, and the European MSG. The ERAU GOES data comes from the Unidata ADDE ingestors/servers (GOESEAST.UNIDATA.UCAR.EDU) via the

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internet. Telvent has their own GOES-east and west antenna and ingestors. The GOES-east and west data include the 30 minute hemispheric scans, the 3 hourly full disk scans, the 15 minute CONUS scans, and the 7 ½ minute CONUS scans when available. The Japanese MTSAT data comes from the NEDSIS public ADDE server (PUB at SATEPSANONE.NESDIS.NOAA.GOV). The MTSAT is available for 30 minute Northern Hemispheric scans and hourly Southern Hemispheric scans. The Chinese FY-2D data is also obtained from the NESDIS PUB server. The FY-2D data is generally 30 minute Northern Hemisphere and hourly Southern Hemisphere. The ERAU European MSG data comes from the NESDIS PUB server and is available only every 6 hours. Telvent has offices in Spain which receive the 15 minute MSG data. Consequently for the ERAU global data sets have minimum coverage provided by the MSG, while the Telvent data have a maximum area of coverage for MSG data.

The image processing is done on the original satellite projections and then remapped into standard longitudinal regions for combining into output mosaics. The global mosaic is a 4 km data set (480x9984 pixels) and is generated every 30 minutes. Over the CONUS regions the GOES data is processed into 2 km IR/1 km visible data sets every 15 minutes (7 ½ minutes when the satellite is in Rapid Scan mode). Two CONUS data sets are generated; an eastern and a western. Both cover the same region (4704x12520 pixels) of the US and the Pacific, but the timing for the eastern mosaic is dictated by the scanning of the GOES-east while the western mosaic timing is dictated by the GOES-west. In addition to the 15 minute CONUS regional mosaics, the Telvent processing also has a 15 minute regional mosaic over Europe at the 1 km visible/2 km IR resolutions.

The data processing is based on the McIDAS software package obtained from the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison. The output data sets are available in the original AREA formats, in JPG (or GIF) sectors for web displays, and GIS Geo-TIFF format data sets for use by Geographic Information Systems (GIS) ARCVIEW and other ARC software.

3. Day/Night Visible Images

The intent of the Day/Night visible images is to have an image of the low clouds and fog which is continually available. The processing is described in more detail in Mosher (2006). Visible brightness is first normalized by dividing by the cosine of solar zenith angle. Then the visible image is divided into two sub-images (visible pixels with IR temperatures colder than 500 mb temperature and visible pixels warmer than 500 mb temperature). The two sub-images are assigned different brightness ranges and then recombined into a single image. The portions of visible image higher than 500 mb are tinted blue using enhancement tables while the portions of visible lower than 500 mb remain black and white. Nighttime portion of image have “fog” images derived from the difference of 3.9 and 11 micron IR channels. The channel differences are caused by differences in particle sizes, which results in different cloud emissivity. The “fog” image allows one to see the low clouds, even if they are the same physical temperature as the ground. The image processing of the “fog” generation is tuned to make low clouds white. In the original processed image, the ice clouds have a dark appearance. To make the image more “visible like”, the dark pixels are replaced with IR values and the same 500 mb split of image as visible leaves the high clouds with a blue tint. Figure 1a shows the global day/night visible image for July 20th 16:30Z. The image has been reduced in size to show the extent of the data set. Figure 1b shows a 4 km detail of a portion of the image showing a hurricane west of Mexico. Figure 1c shows a blow down of the day/night CONUS sector for July 21, 2001 at 15:15Z, while figure 1d shows show a detail of the 1 km data of a thunderstorm over eastern Kentucky and Tennessee.

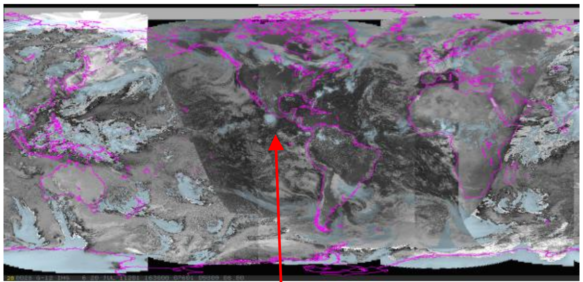

Figure 1a. Global Day/Night visible image for July 20, 2011 at 16:30Z. The blue tint areas are for clouds above 500 mb.

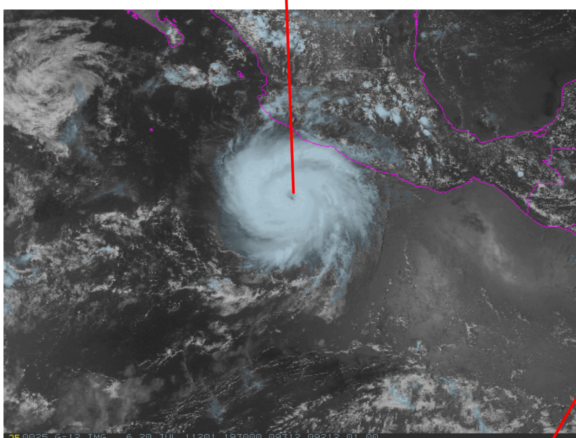

Figure 1b. 4 km Day/Night image of the Hurricane west of Mexico in figure 1a.

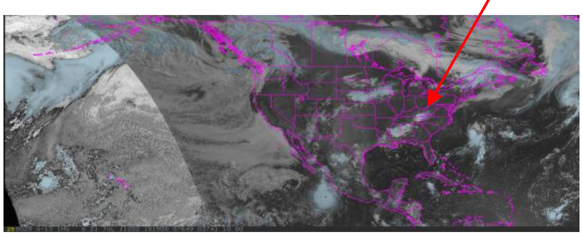

Figure 1c. CONUS sector of the Day/Night for July 21 2011 at 15:15Z.

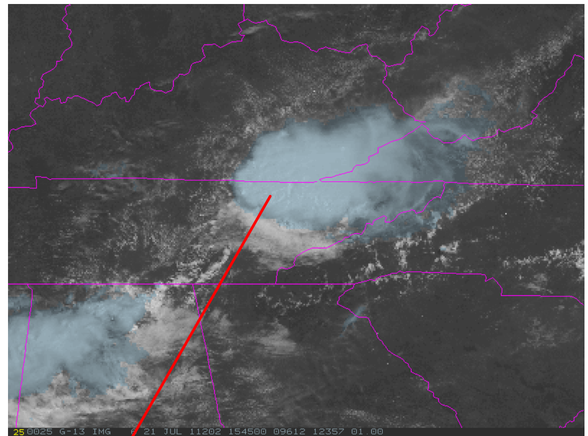

Figure 1d. 1 km resolution detail of figure 1c showing thunderstorm over eastern Tennessee.

4. Albedo/Night Images

The Day/Night visible images consist of two sub-images with different gray scales for the lower and upper clouds. The image display requires use of enhancement tables to stretch the brightness scales of each sub-image into the full dynamic range. For applications which don't use complicated enhancements, an Albedo/Night image is made available. It is the same as the Day/Night visible, except it does not have the two sub-ranges of brightness. It looks more like traditional visible images. Figure 2a shows the global image for the same data as figure 1a, and figure 2b shows the 4 km detail of the hurricane shown in figure 1b.

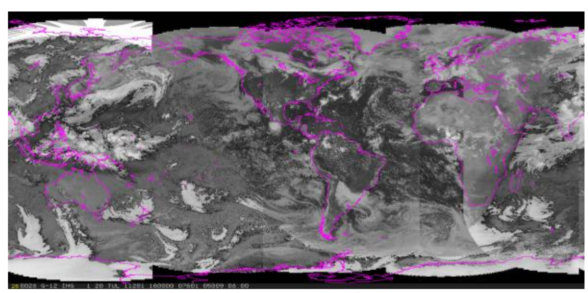

Figure 2a. Albedo/Night image of global mosaic for July 20, 2011 at 16:30Z. Data is the same as the Day/Night images of figure 1a, except it is only black and white.

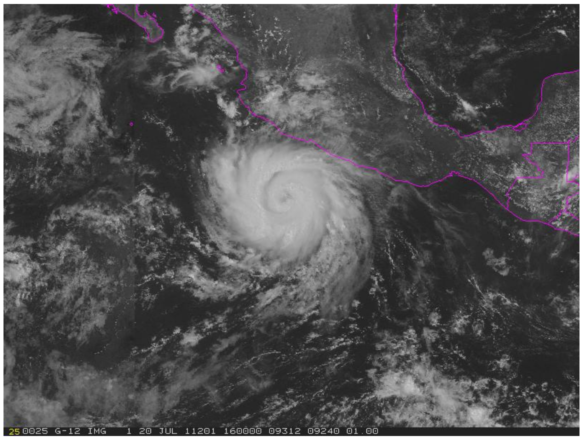

Figure 2b. Same 4 km detail as figure 1b for the Albedo/Night images showing the hurricane off the coast of Mexico

5. Infrared Images

Infrared images (11 micron) are generally used to monitor thunderstorms and high clouds. The infrared mosaic is generated using the original temperature calibration provided by the satellite providers. No corrections have been made for limb darkening or calibration differences. Figure 3a shows a blow down of the global mosaic, with figure 3b showing the 4 km hurricane sector. The enhancement is used for display has the blue colors from -38°C to -57°C, the reds from -58°C to -77°C, and greens from -78°C to -89°C.

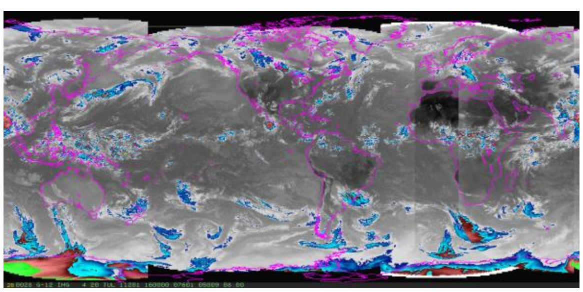

Figure 3a. Global mosaic of 11 micron infrared images for July 20, 2011 at 16:00..

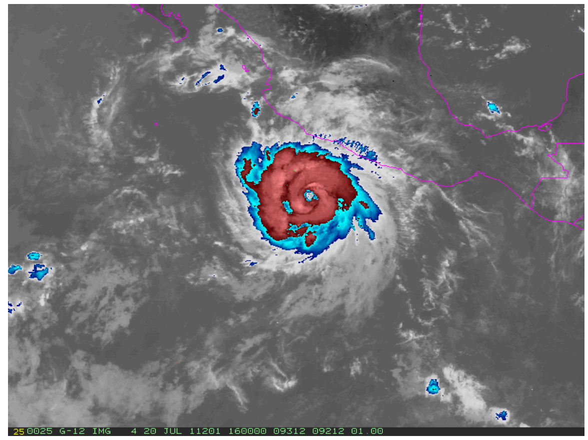

Figure 3b. 4 km detail of the 11 micron infrared image showing the hurricane off west coast of Mexico. The enhancement used for the display has blue colors from -38°C to -57°C and the reds from -58°C to -77°C.

6. Convective Diagnostic

The convective diagnostic is designed to identify strong convective storms, such as those identified by Convective SIGMETs. The processing is described by Mosher (2002) and Mosher (2003) and the validation is presented in Martin et.al. (2008). The convective diagnostic uses the difference between IR and Water Vapor images. When the difference is near zero, the cloud is high (no water vapor above the image and thick (no transmission of infrared radiance through the cloud). To eliminate none-convective high, thick clouds the K index is used. The global K index is obtained from the GFS model and mapped into the satellite projection. K index values of less than 20 are used to filter out none-convective regions. Displays of the convective diagnostic use IR data to show clouds. Pixels with a positive convective diagnostic are shown in red. The processing also computes height of cloud top and generates a convective cloud top image (not shown). Figure 4a shows the global convective diagnostic for the same time as the infrared figure 3a, and figure 4b shows the same 4 km detail of the hurricane off Mexico.

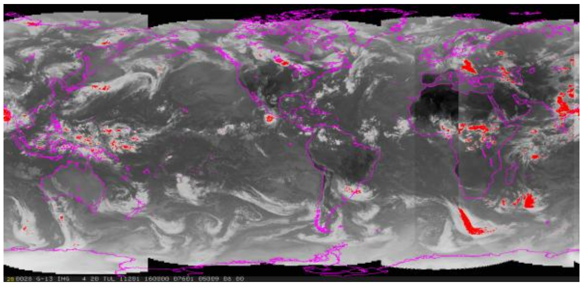

Figure 4a. Global Convective Diagnostic for July 20, 2011 at 16:00. Same location and time as the infrared image in figure 3a.

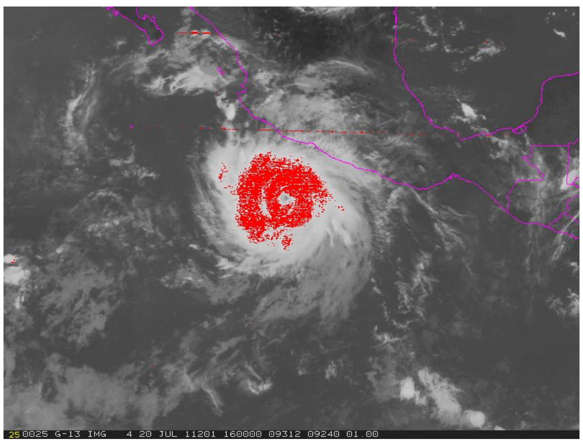

Figure 4b. Same location as figure 3b showing the 4 km detail of the hurricane off the Mexican coast on July 20, 2011 at 16:00.

7. Water Vapor

Water vapor data (6.7 micron channel) from the various satellites are processed without brightness modification for limb darkening. Enhancement tables used for display bring out details in the images. Figure 5a shows the global water vapor composite for July 20, 2011 at 16:00Z and 5b shows the 4 km detail of the hurricane off Mexico.

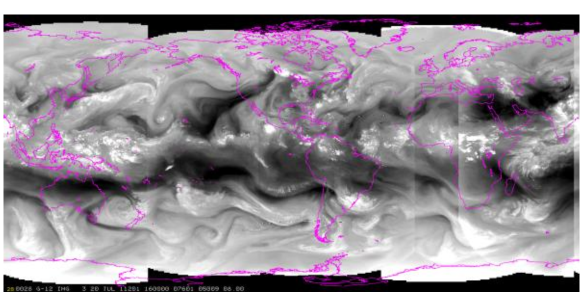

Figure 5a. Water vapor (6.7 micron channel) mosaic for July 20, 2011 at 16:00.

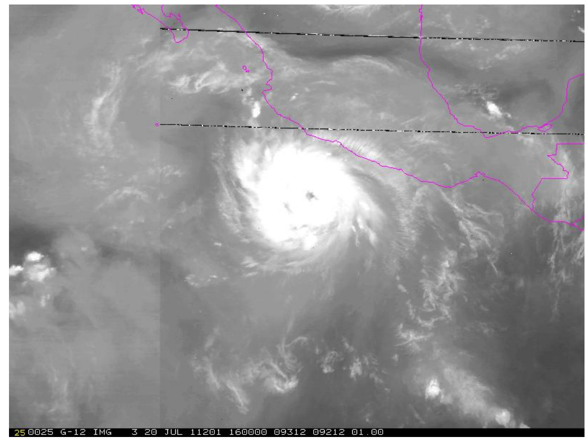

Figure 5b. 4 km detail of the hurricane in the water vapor image for July 20, 2011 at 16:00.

8. Volcanic Ash

Volcanic ash clouds are generally difficult to distinguish from ordinary water clouds on satellite images. The traditional method is the “dirty window” method of using the difference between the 11 & 12 micron channels. This method can be applied to the current GOES-west (GOES-11), the Japanese MTSAT, and the European MSG satellites. The GOES-12 through GOES15 (current East and South American satellites and the eventual replacement for GOES-west) do not have a 12 micron channel. A substitute algorithm is used for GOES-east which consists of the difference between the 11 and 3.9 micron channels modified by the visible channel. The 11-3.9 micron difference is sensitive to particle size. Since the volcanic ash particles which are hazardous to aircraft are large, they show up on this difference. However cirrus clouds also show up in this product in addition to ash clouds. An additional problem in using the 3.9 micron channel during the day is that the solar spectrum has a component at the 3.9 micron region. In order to reduce the reflected solar 3.9 micron radiation, a fraction of the visible is subtracted from the difference product. The basic concepts of the ash processing using the 3.9 micron channel are described in Mosher (2000). The

Chinese FY-2D satellite has a 12 micron channel, but there are rise time differences between 11 and 12 micron channels. When the 11 and 12 micron channels are differenced, the edges of the clouds show up, which makes its use for ash difficult. For the Telvent products, the MSG ash sector has been extended toward India to reduce the area covered by the FY-2D. For the ERAU products, the GOES-east ash algorithm is applied to the Chinese FY-2D sectors. Figure 6a shows the global mosaic of ash products. Figure 6b shows a 4 km detail of North Africa showing a dust storm. Figure 6c shows volcanic ash in South America on June 13, 2011 at 18:15Z for the GOES-east 3.9-11 algorithm. Figure 6d dust over Iraq on May 29, 2011 at 16:45Z.

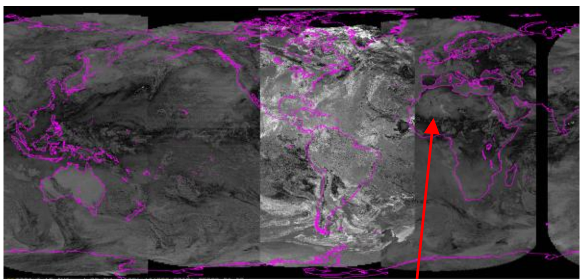

Figure 6a. Global mosaic of ash products for July 20, 2011 at 16:15Z. Note the GOES-east area has a different algorithm because of the lack of a 12 micron channel.

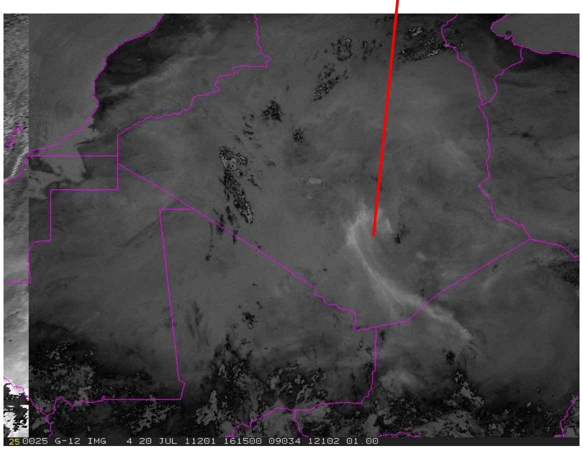

Figure 6b. A dust storm in North Africa on July 20, 2011 at 16:15Z. The ash “dirty window” 11-12 micron difference is used to show the dust.

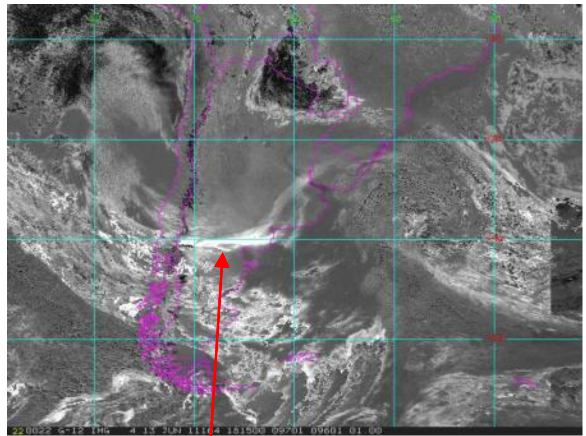

Figure 6c. Volcanic ash on June 13, 2001 at 18:15Z detected by the 11-3.9 micron difference algorithm used for GOES-east.

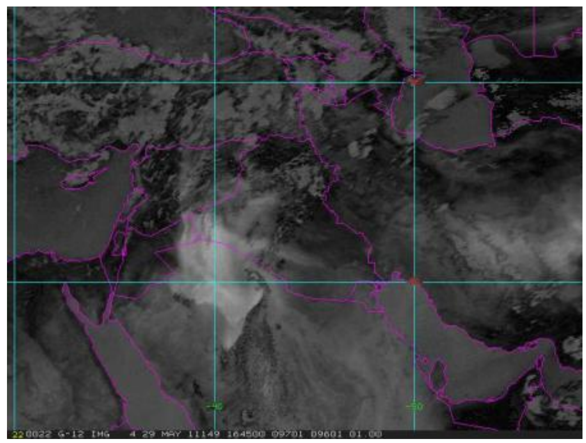

Figure 6.d. Dust over the Middle East on May 29, 2011 at 16:45 detected by the 11-12 micron difference algorithm using MSG data.

9. Product Availability

The satellite image processing is done independently at both ERAU and Telvent. The ERAU data can be accessed on the web at http://wx.erau.edu/erau_sat. The information on the Telvent products can be accessed at http://www.telvent.com/en/business_areas/environment/solutions_overview/aviation/. The digital data from ERAU will be available via ADDE soon. Please contact the primary author for ADDE address information.

10. References

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