9A.2 Tropical Cyclone Satellite Tutorial Online Through The COMET Program

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1. Introduction

The Cooperative Program for Meteorology, Education and Training (COMET) has produced an online educational module that introduces forecasters to observation and analysis of tropical cyclones. Sponsored by the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO), this module foresees forecaster applications when the NPOESS Preparatory Project (NPP) and NPOESS satellites are launched starting later this decade. The training, however, can be used now. Even as it previews modernized applications, the module reviews important capabilities from existing polar-orbiting satellite sensors including Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) (and SSMIS, final "S" standing for sounder), Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), NASA Aqua Advanced Microwave Scanning Radiometer (AMSR-E), Coriolis WindSat, and NOAA Advanced Microwave Sounding Unit (AMSU-B). The module is freely available to the public and takes about one hour to complete. While the content is designed for personnel with basic training in meteorology or oceanography, the general public may also find it useful. The module is voice narrated and interactive, ending with a quiz to test comprehension of key concepts. Feedback received from surveys indicates that a wide variety of users worldwide are benefiting.

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2. The COMET Program

The COMET Program has provided distance-learning education to a wide spectrum of users in the atmospheric science community since 1990. Distance-learning technologies applied by COMET focus on Web-based training modules, teletraining offerings developed in conjunction with the NOAA/NWS VISIT (Virtual Institute for Satellite Integration Training) program, and course that blend distance-learning with residence attendence. COMET also has the capacity to offer a variety of residence courses and workshops in its classroom facility in Boulder, Colorado.

The full exploitation of improved information resulting from rapid advances in global observing systems like NPOESS is contingent upon strong education and training processes. For the NPOESS IPO, the COMET program's focus is on highlighting and demonstrating the future capabilities and applications of the NPOESS system for operational forecasters and other user communities. COMET works closely with these user communities to stimulate greater utilization of both the training materials and current operational and research polar-orbiting satellite data observations and products.

To meet these goals, the NPOESS training effort generates web-modules, teletraining sessions, webcasts, workshops, and maintains a Web-based information resource portal, the NPOESS Userport. The Userport Website provides links to polar-orbiting satellite multimedia learning resources and real-time data for forecasters, scientists, and the general public interested in learning more about the mission, spacecraft, instrumentation, data processing, products, and applications: http://meted.ucar.edu/npoess/

3. Satellite Training on Tropical Cyclones at the Naval Research Laboratory

The Naval Research Laboratory (NRL) Monterey is charged with providing appropriate examples and content to COMET developers to demonstrate future NPOESS capabilities. With respect to tropical cyclones, NRL is uniquely positioned for this role because of its web site which shows live satellite images, especially from microwave sensors, for every storm on a global, year-round basis: (http://www.nrlmry.navy.mil/tc_pages/tc_home.html) using existing satellite data streams from polar and geostationary satellites (Hawkins et al. 2001; Lee et al. 2002). The Tropical Cyclone Analysis module which focuses on the use of passive microwave images for the analysis and fixing of tropical cyclones (front page shown in Fig. 1) is one of the most popular COMET modules on satellite meteorology: http://meted.ucar.edu/npoess/tc_analysis/

The module is divided into ten sections (Table 1) with illustrations and example products appearing throughout. There are also tables to summarize key information (e.g., Table 2). The module emphasizes the difference between infrared images, the standard used for analyzing tropical cyclones, and passive microwave images that have been increasingly used by forecasters since the launch of the first SSM/I in 1987. Fig. 2 shows an example of an infrared image of Hurricane Frances in 2004, showing a cirrus canopy with low temperatures in red near the center. Fig. 3 is the corresponding composite based on observations from the U.S. Navy research and development microwave sensor, WindSat, aboard the Coriolis satellite. The microwave data reveals a double eye wall structure that is hidden beneath the cirrus canopy on Fig. 2.

Fig. 4 also demonstrates concentric eyewall characteristics, but this time for Hurricane Juliette in the Eastern Pacific based on TRMM TMI data. Figs. 5 and 6 present a quiz question, the former asking the question and the latter showing the answer. The interspersed questions throughout the module help reinforce key elements of the material and accelerate learning. Fig. 7 shows the difference between cross track and conical scan strategies. Both strategies are used in the passive microwave imaging of tropical cyclones, but there are important ramifications to the use of each. In Fig. 8 we see the distortion arising at the edge of scan with the cross-scanning arising from the AMSU-B sensor. Fig. 9 illustrates how satellite parallax creates displacement of elevated features, such as clouds, with respect to the earth. Fig. 10 illustrates the effect of parallax on microwave images.

4. Other NRL Training

NRL also maintains training on its NexSat satellite site (Miller et al 2006): http://www.nrlmry.navy.mil/NEXSAT.html/. This site is a realtime display of a number of experimental satellite products to illustrate advances in polar satellite capabilities in anticipation of NPOESS. Products which blend geostationary and polar capabilities are also emphasized, for example “geostationary color” as shown in Fig. 11. This example of Hurricane Katrina shows visible data overlaid upon the NASA blue marble background during the daytime. At night infrared data are overlaid upon a background that incorporates nighttime city lights from the National Geophysical Data Center (NGDC). The NexSat page contains a detailed training tutorial in pdf form (green button shown in Fig. 12). Similar training product tutorials are available for all of the experimental applications listed on the left side (“Products” list) of the interface.

5. Acknowledgements

The support of the research sponsor, the National Polar-orbiting Operational Environmental Satellite System’s (NPOESS) Integrated Program Office (IPO) located in Silver Spring, MD, is gratefully acknowledged. The support of the research sponsors, the Oceanographer of the Navy through the program office at the PEO C4I&Space/PMW-180, under program element PE-0603207N and the Office of Naval Research under program element PE-0602435N is gratefully acknowledged.

6. References

Hawkins, J.D., T. Lee, J. Turk, C. Sampson, J. Kent, and K. Richardson, 2001: Real-time Internet distribution of satellite products for tropical cyclone reconnaissance. Bull. Amer. Met. Soc., 82, 567-578.

Lee, T.F., F.J. Turk, J.D. Hawkins, and K.A. Richardson, 2002: Interpretation of TRMM TMI images of tropical cyclones. Earth Interactions E-Journal 6:3.

Miller, S. D., J. D. Hawkins, J. Kent, F. J. Turk, T. F. Lee, A. P. Kuciauskas, K. Richardson, R. Wade, and C. Hoffman, 2006: NEXSAT: Previewing NPOESS/VIIRS Imagery Capabilities, Bull. Amer. Met. Soc., in press (April issue).

Table 1
Table of Contents
Using Microwave Observations for Tropical Cyclone Analysis

Table 2
Comparing Active and Passive Microwave Sensors

Passive Microwave Remote Sensing	Active Microwave Remote Sensing
Sensor Examples	
AMSU, AMSR-E, SSM/I, SSMIS, TRMM-TMI, WindSat, CMIS	QuikSCAT, TRMM-PR, RADARSAT, ASCAT, CloudSat
Measurement Capabilities	
Sense microwave energy emitted naturally	Send and receive electromagnetic pulses of energy
Atmospheric and cloud information from layers	Atmospheric and cloud information from discrete levels
Sea surface wind vectors, salinity	Sea surface wind vectors, ocean waves, salinity
Precipitation (rain rate and snowfall)	Precipitation (rain rate and snowfall)
Cloud ice and cloud water	Cloud ice and cloud water
Atmospheric temperature and moisture	
Snow cover/depth and sea ice/concentration	Sea ice/monitoring extent
Snow water equivalent	
Soil Moisture/Surface Wetness	Soil Moisture/Surface Wetness
	Vegetation, biomass, land use, surface roughness, topography, and geology (ASCAT, RADARSAT)

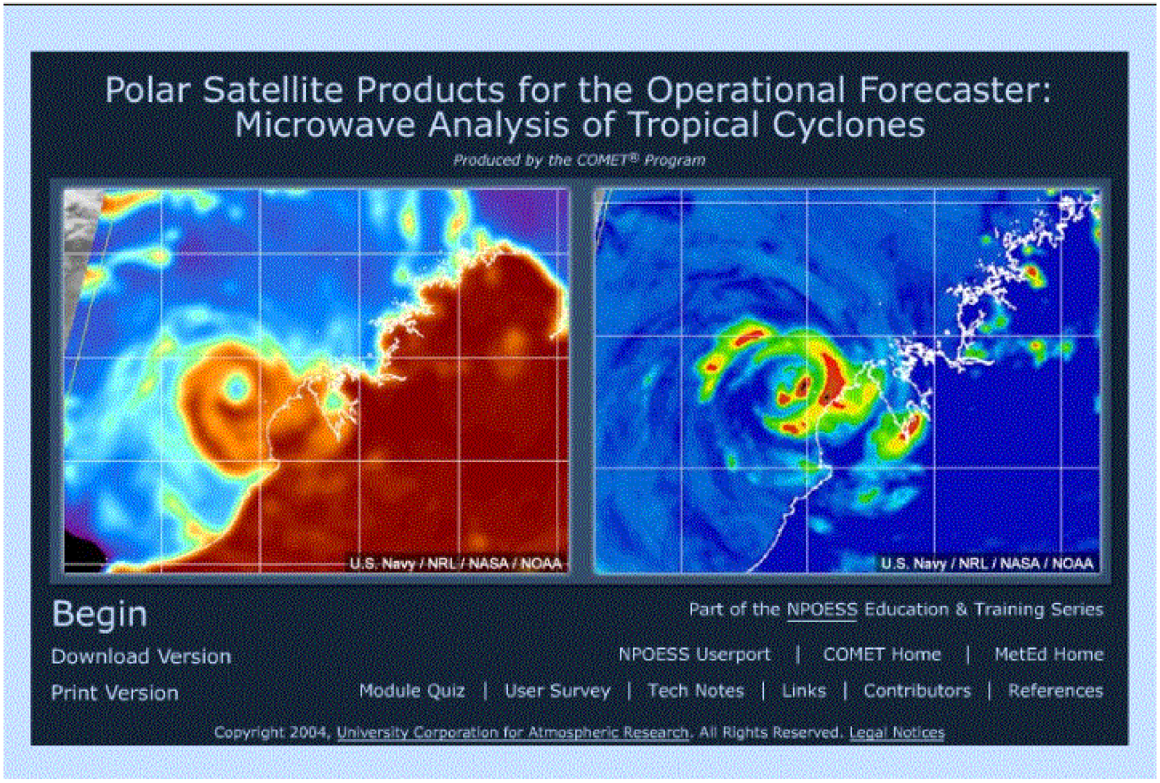

Fig. 1 "Front Cover" of Tropical Cyclone module.

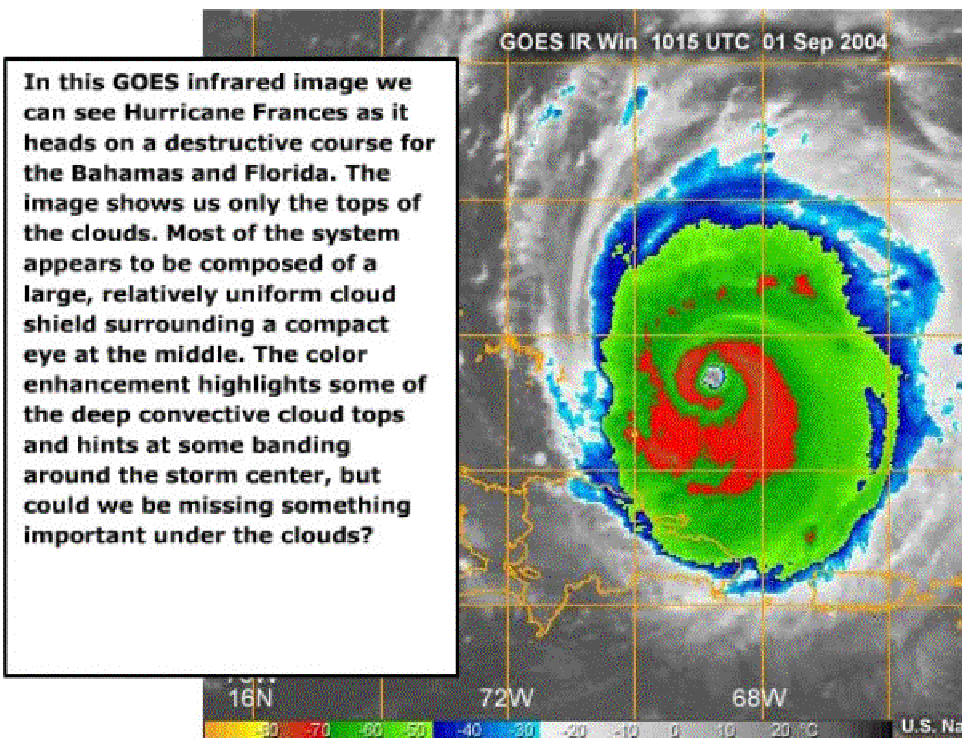

Fig. 2 Example IR image of Hurricane Frances. Shows text box from the online original version.

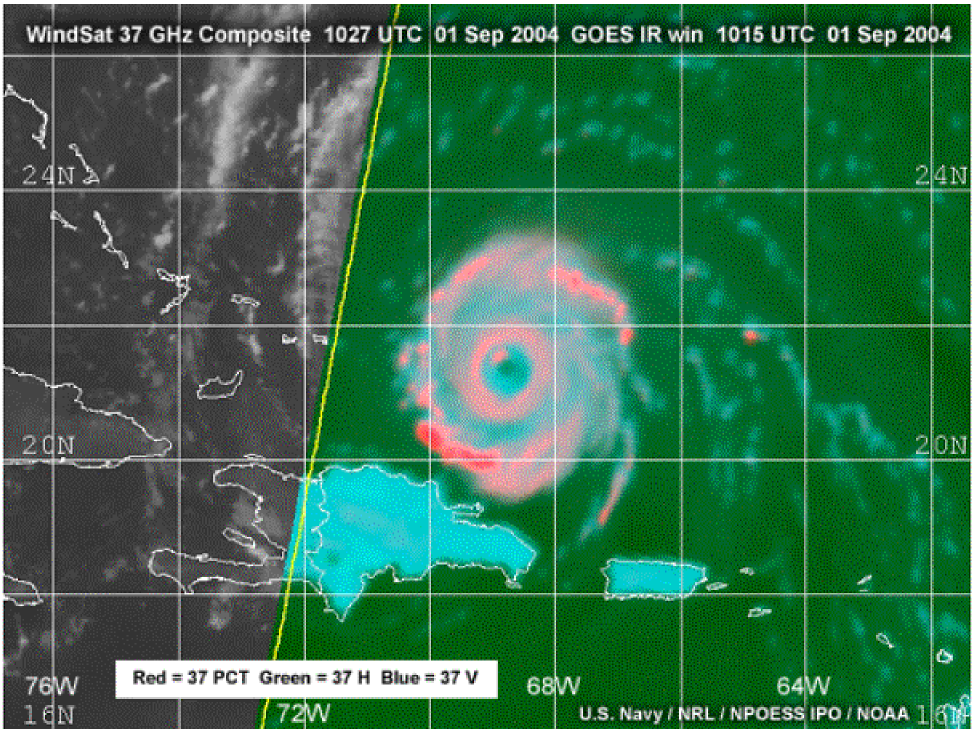

Fig. 3 WindSat 37 GHz composite image of Hurricane Frances corresponding to IR image in Fig. 2. Pink indicates deep convection and marks a double eyewall formation.

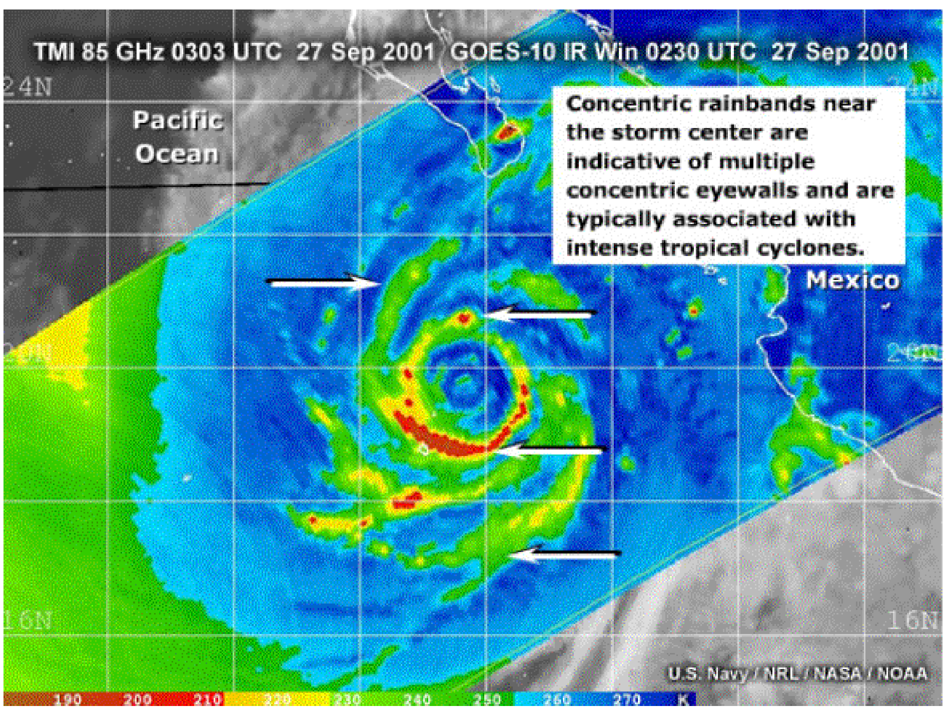

Fig. 4 Hurricane Juliette in the Eastern Pacific showing concentric eyewall characteristics. Image is from the TRMM TMI 85 GHz channel.

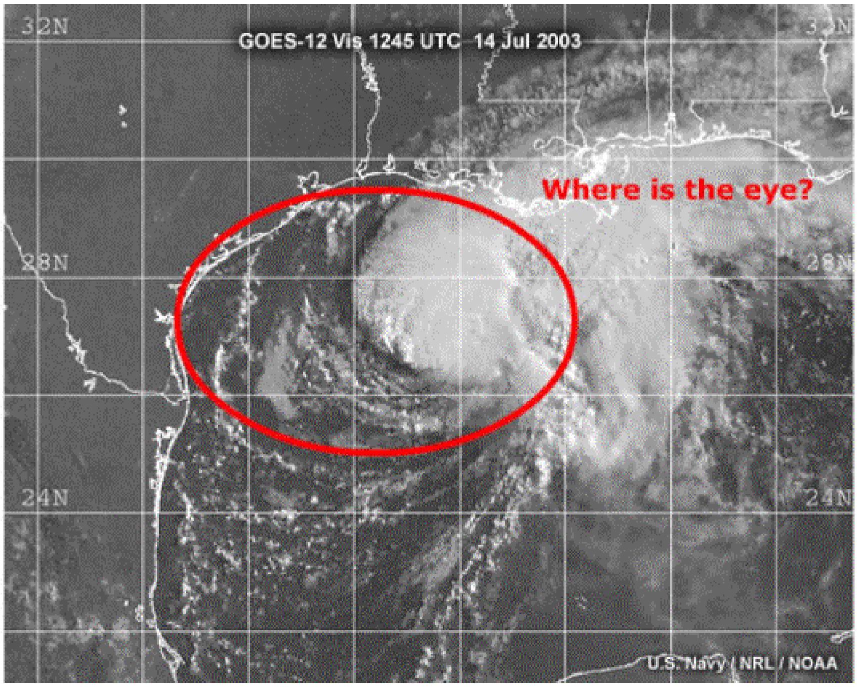

Fig. 5 First panel in a quiz to test understanding of relatively weak tropical cyclones. Image shows a GOES visible image, on which the user is asked to identify the center of circulation.

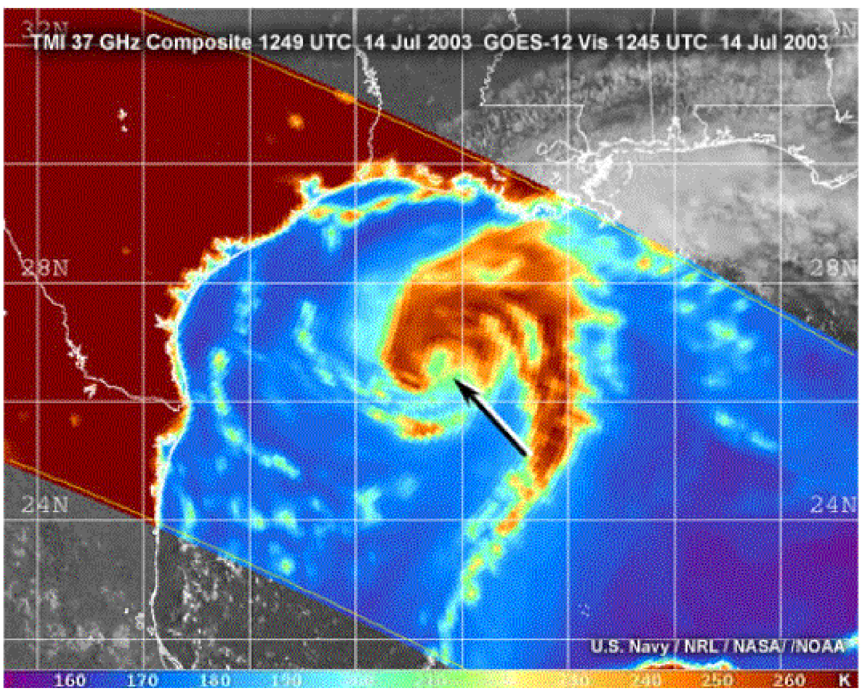

Fig. 6 Second panel on a quiz on tropical cyclone circulation centers. TRMM TMI 37 GHz image reveals eye that was hidden on the visible image in Fig. 5.

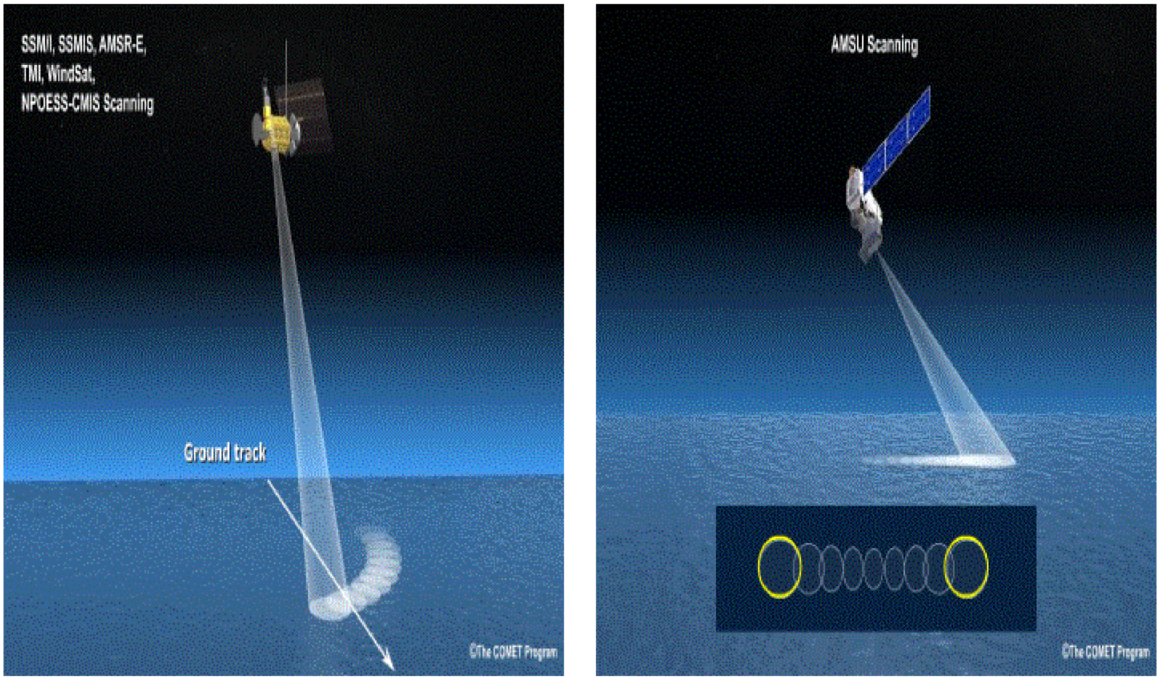

Fig. 7 Schematic illustrating difference between conical scanning (left) and cross-track (right) scanning microwave sensors.

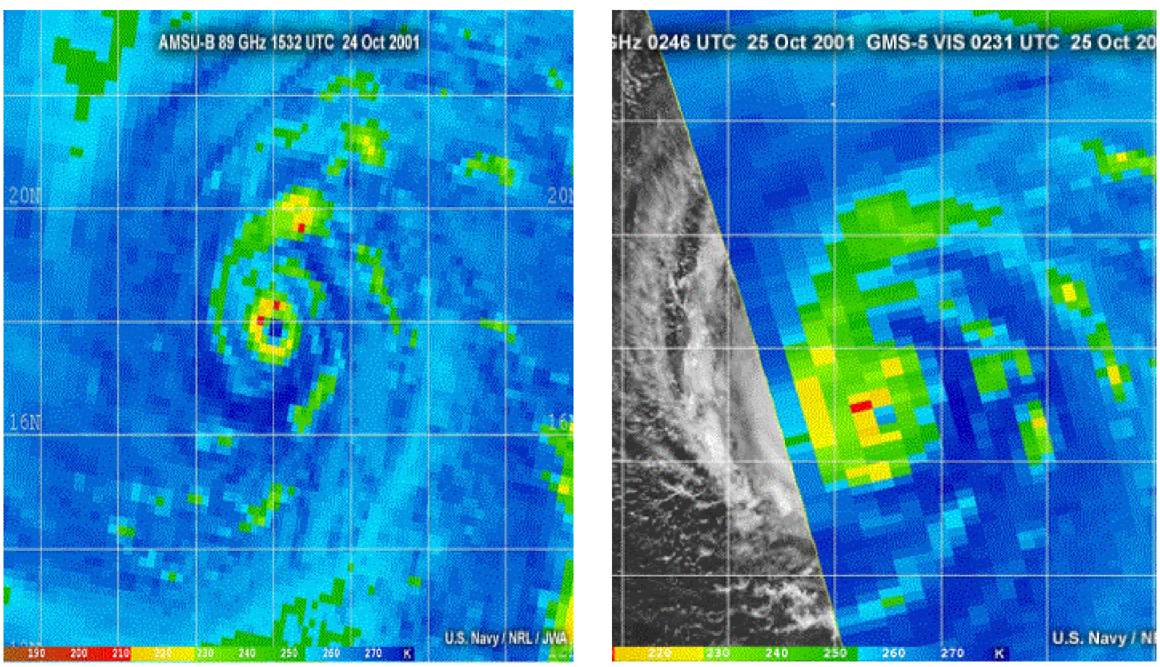

Fig. 8 AMSU-B 89 GHz images at center of scan on left and edge of scan (note distortion) on right.

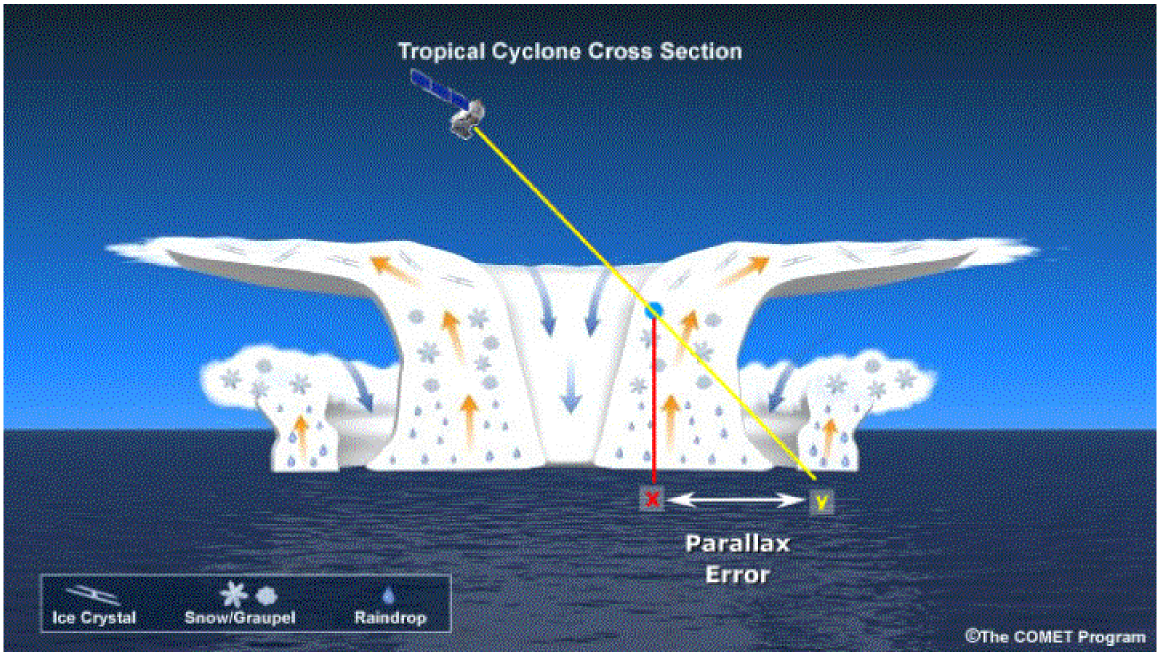

Fig. 9 Illustration of parallax error within a tropical cyclone. The feature imaged above point x (blue dot) is displaced to point y on images.

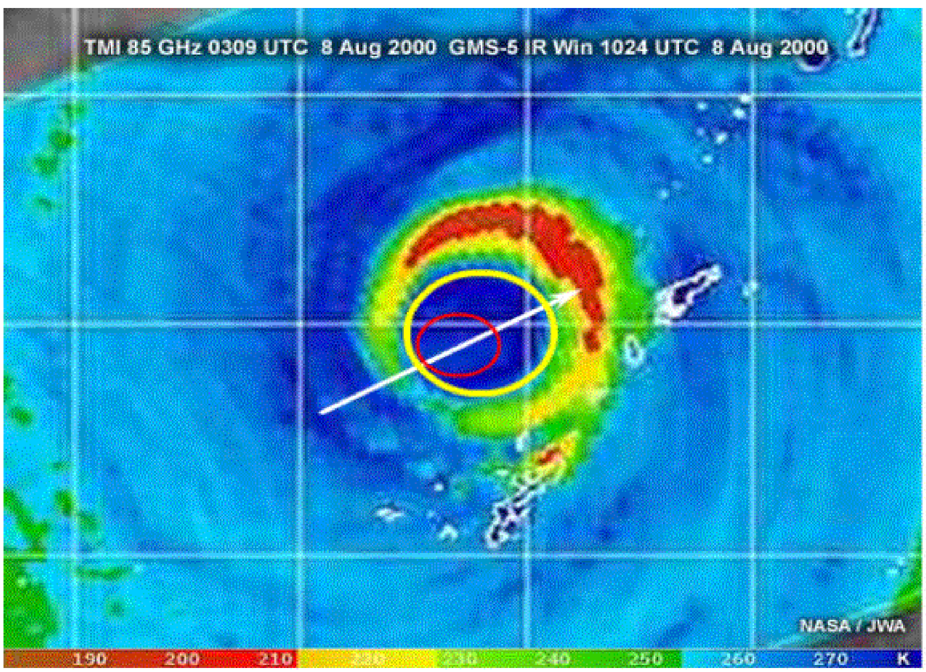

Fig. 10 Illustration of parallax errors using images from different microwave frequencies. The red circle represents the eye location from a 37 GHz image (image not shown); the yellow circle represents the eye location from the image shown at 85 GHz. The difference in location is based on parallax.

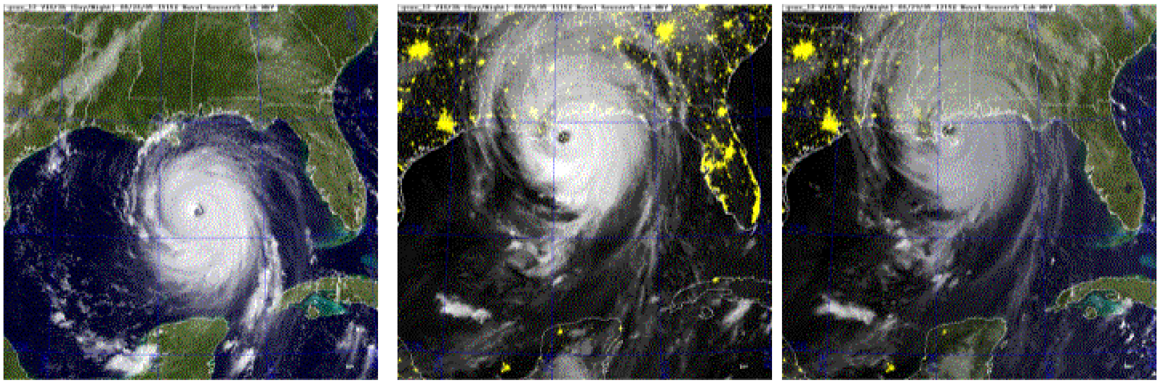

Fig. 11 Geostationary color products showing Hurricane Katrina moving onshore. Image on the left is a daytime image with GOES visible data overlaid on the NASA blue marble background. Image in the center shows the next night with infrared data overlaid on the NGDC nighttime lights data base. Image on the right is at around sunrise the next day with a blend of visible/infrared data on top of NGDC nighttime lights (left, west side) and blue marble background (right, east side).

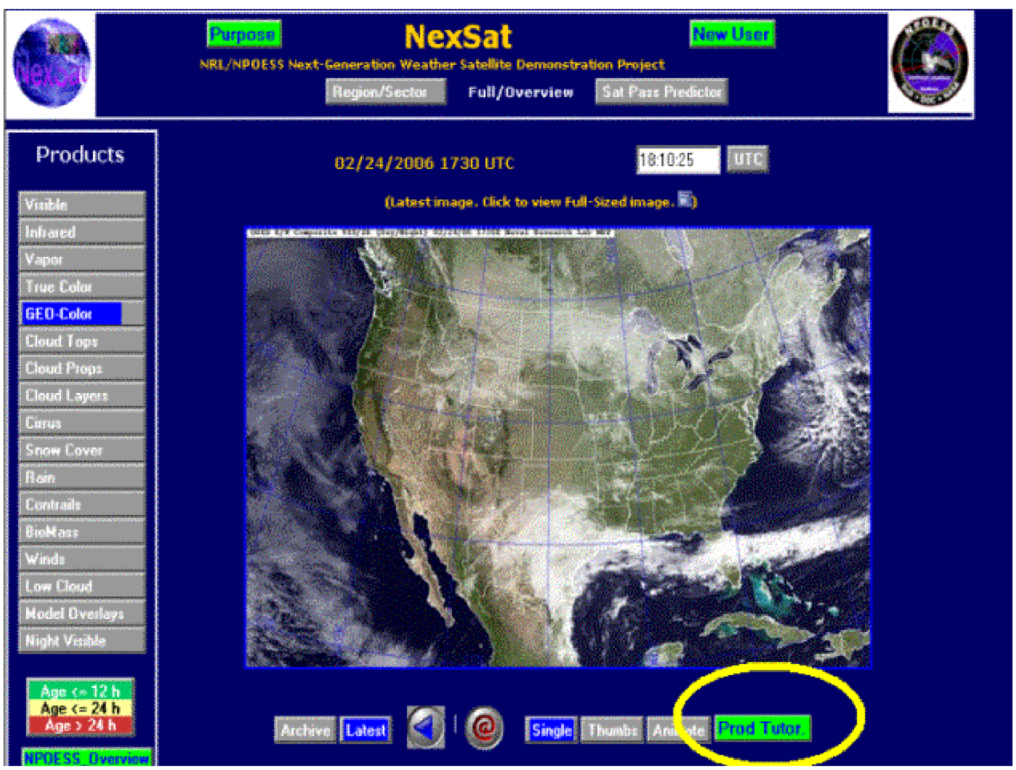

Fig. 12 NexSat site: http://www.nrlmry.navy.mil/NEXSAT.html/
Circled button shows how to access training information about Hurricane Katrina.