NAVY SATELLITE METEOROLOGICAL APPLICATION PRODUCT DEMONSTRATIONS

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1. OBJECTIVE:

Satellite remotely sensed data must be effectively utilized in order to mitigate the numerous data voids the US Navy faces around the world. These data gaps in weather information are especially prevalent over the ocean's within which the Navy operates as well as in the regional conflict domains that have become the primary focus of recent US peacekeeping efforts. Routine data collection is either too expensive due to the shear size of the area of responsibility (AOR) or denied from standard stations during periods of war/conflict. Satellite digital data can broach this data void issue with a potential wealth of timely, accurate measurements that can be distributed to DoD units via several methods, including secure Internet links.

The variety of Navy meteorology requirements dictates the use of both geostationary and polar orbiter data and the ability to take advantage of inherent sensor capabilities. Multi-sensor combinations then enable the creation of enhanced and new products that would not have been feasible with the use of any given single sensor. A primary goal is to provide the customer with a toolbox of sensible weather information that can be used for both nowcasting and as input to numerical models for enhanced multi-day forecasting prognostications.

2. RESEARCH ACCOMPLISHED

Timely access to global, digital satellite data streams is critical to the success of NRL-MRY's mission. Five geostationary data sets are currently collected to enable global applications to run in near real-time. GOES-8/10, GMS-5, and Meteosat-5/7 digital data are gathered and placed into a common data format. The TeraScan Data Format (TDF) permits the user to readily ingest, process and display visible, Infrared (IR) and water vapor imagery from any of the satellites.

Global polar orbiter data from the Special Sensor Microwave/Imager (SSM/I) and the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) are also accessed in near real-time. The passive microwave data from the four active SSM/Is and one TMI sensor provides a wealth of information not available from vis/IR and water vapor channels on geostationary satellites. Although the timeliness of the data is typically older than that for geostationary data, the passive microwave data are critical to several applications.

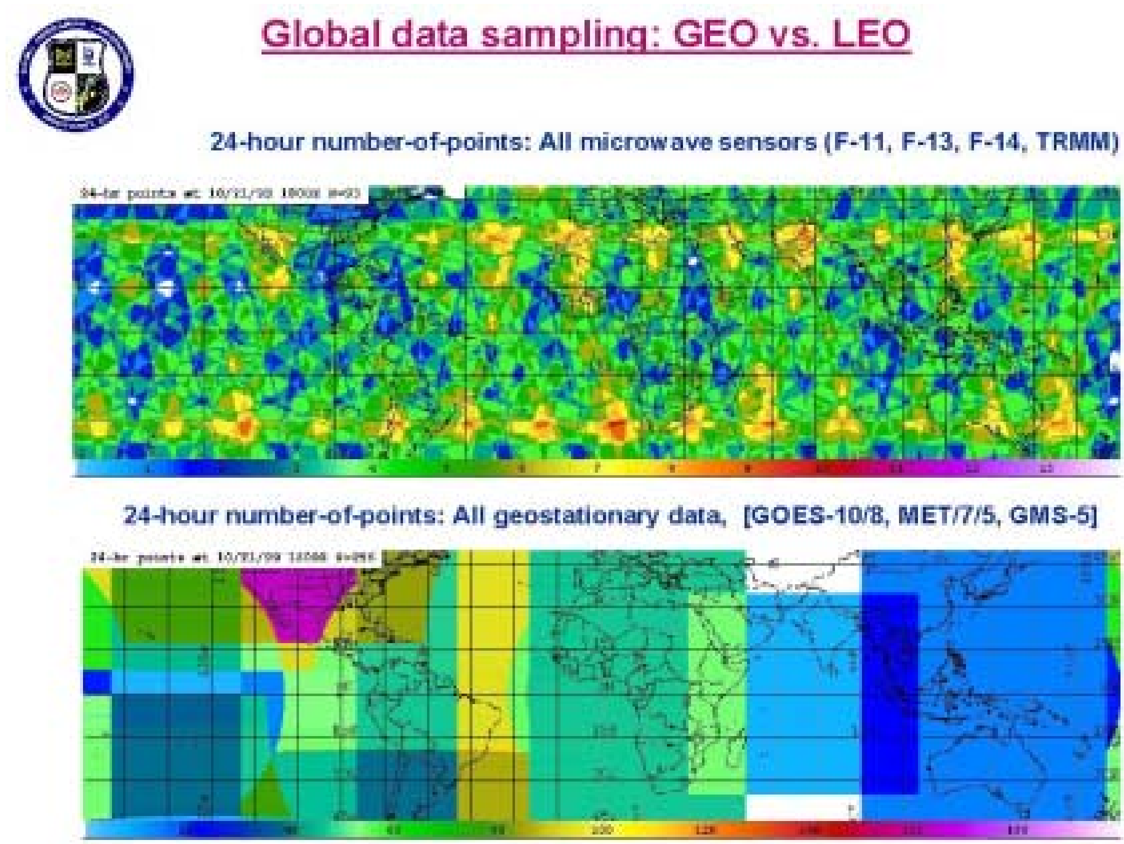

Figure 1: The total number of satellite observations provided by both passive microwave and geostationary sensors is displayed in the top and bottom panels respectively (note the geostationary scale is an order of magnitude larger) for one 24-hour period. Passive microwave sampling peaks near 37 deg due to the addition of TRMM data. Geostationary data is a patchwork quilt that reveals the various sampling strategies employed with each satellite. Meteosat-5 data does extend beyond 40 deg, NRL simply does not receive data for the full disk.

NRL-MRY thus processes a very large remote sensing data set in near real-time as illustrated in Figure 1. This large processing step is readily feasible with today's cost effective computational capabilities. Specific single and multi-sensor applications are then performed and posted to the NRL satellite web page:

http://www.nrlmry.navy.mil/sat_products.html

The main satellite meteorology web page is shown in Figure 2 and includes the following products; a) visible, IR and water vapor images for many parts of the US, the Atlantic/Pacific basins and the tropics, b) tropical cyclone web page that follows active storms around the globe (Hawkins, et. al., 2000, Lee, et. al., 1999), c) rainrate retrieval scheme that combines geostationary IR with passive microwave data (Turk, et. al., 1999), d) automated cloud classification (Tag, et. al., 1999), e) cloud top height product for the US and Pacific ocean basin, f) geostationary winds in collaboration with the U. of Wisconsin (Velden, et. al., 1997), g) low cloud detection 24 hours/day (Lee, et. al., 1998), and h) multi-sensor comparisons of passive microwave and geostationary data around the globe.

Figure 2. NRL-MRY satellite meteorology applications main web page. Users can select a product of choice and navigate swiftly from one product to another. Each product is typically applied to more than one geographical region and the user can select the domain on the next page displayed. All products are updated automatically via scripts that key on receipt of data or specific time production cycles.

The entire ingest and processing system is automated and now requires no manual intervention to maintain the routine functionality. The automation of product generation is a key to providing timely, up to the minute products. The user can learn from past examples, but will pay considerably more attention to real-time displays of weather parameters that are impacting his/her decisions during the time that they are viewing the web page. This real-time nature is paramount in keeping the user interested and fosters feedback.

Product feedback is critical to NRL-MRY's goal of creating the highly robust modules for transition to operation. Comments from Navy, academic and general public users have been crucial to modifying products. User insights are a key part of the overall effort and the Internet web page readily enables this highly desired aspect.

The tropical cyclone portion of the web page highlights many of the themes emphasized by NRL-MRY. Warnings are received in near real-time on all tropical cyclones globally. The appropriate geostationary and polar orbiter data streams covering that location are then queried about data availability. This automated process permits the interrogation of visible, IR and passive microwave images/products for each tropical cyclone. In addition, the system coregisters all products, such that user interpretation is simplified considerably. Since upper and mid-level clouds often obscure important tropical cyclone structure details we emphasize the use of passive microwave data that can see through most non-raining clouds and view internal storm structure. Thus, we include a suite of passive microwave images/products to assist the user in understanding the TC structure (Hawkins, et. al., 1996 and Hawkins, et. al., 1998).

The TC web page has several unique features: a) all passive microwave products are storm centered (updated at least every 6-hours), b) collocated visible, IR and IR-BD curve images are produced using the closest geostationary imagery (typically within 15-30 minutes), and c) multi-sensor composites are displayed in two forms. Multi-panel composites with visible, IR, PCT and 85 GHz are displayed in a 4-panel image as well as any data void region in a passive microwave image is now filled in with vis/IR data.

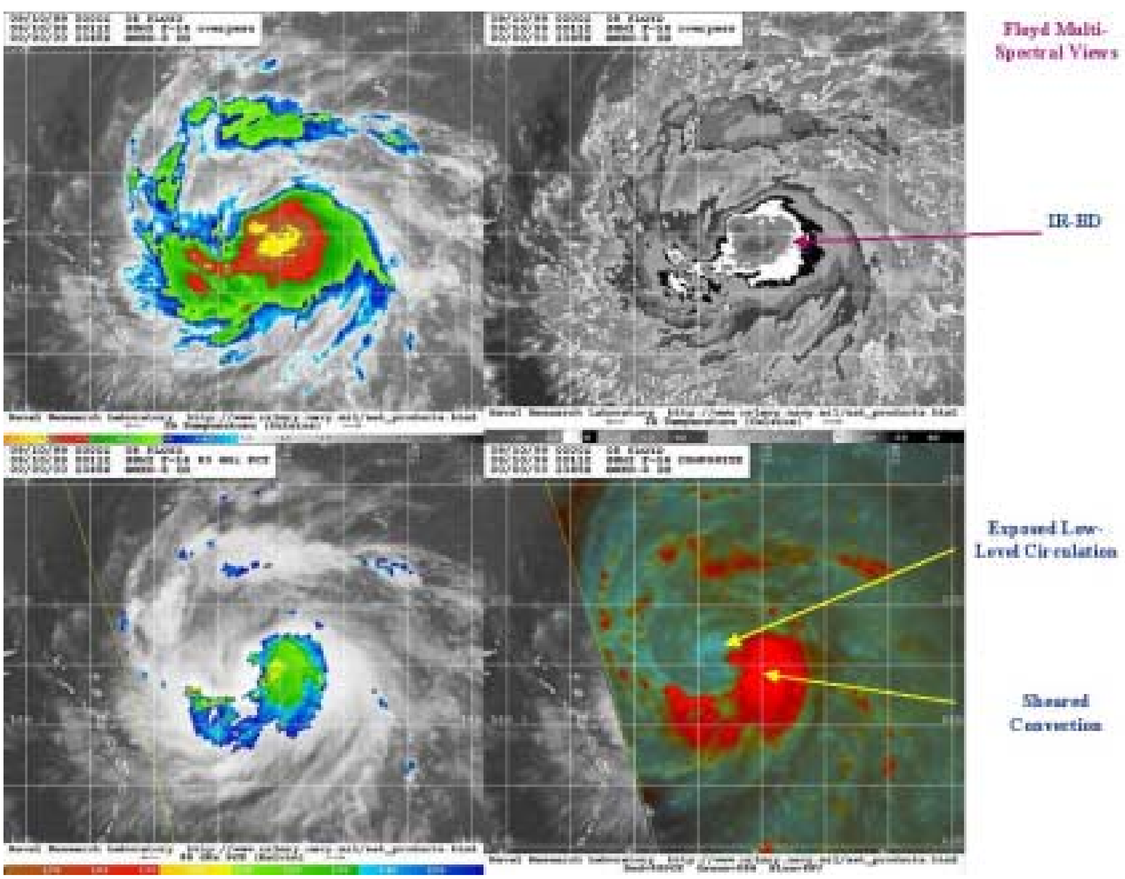

Figure 3. Coincident comparison of geostationary Infrared images along the top row (one false colored, the other enhanced for tropical cyclone applications) and passive microwave products along the bottom. The bottom left panel highlights the area of intense convection via a Polarization Corrected Temperature (PCT) product and the multi-colored product in the bottom right uses the 85 GHz data and the PCT to reveal the low-level circulation is displaced from the main convection to the right (e.g., shear is underway).

NRL-MRY has led the utilization of passive microwave data via our tropical cyclone web page:

http://kauai.nrlmry.navy.mil/sat-bin/tc_home

The sample shown in Figure 3 is just one case that illustrates the potential value of passive microwave data in near real-time analysis of tropical cyclone structure. The structure and its time evolution are vital to understanding the storm's intensity trends and very helpful in completing the overall storm environmental picture.

The second application module is the rainrate product that incorporates both IR cloud top temperatures with collocated passive microwave rainrates. As discussed in detail by Turk, et. al., [1999], passive microwave data is used to basically train the more frequent IR cloud top temperatures. This enables us to create basin and global scale real-time rainrate maps at 30-minute intervals. This product has not only real-time applications, but also can be incorporated into numerical forecast models via the process of physical initialization.

The globe is divided into 15 degree boxes that overlap by 5 degrees, ensuring that similar cloud microphysics are typically encompassed within each sub region. Receipt of passive microwave data initiates processing that accesses the appropriate geostationary data and produces the matchups and probability distribution functions. The lookup table for converting IR cloud top temperatures to rainrate are thus dynamic and changing with time. This is required since no fixed relationship will work as the meteorological environment fluctuates as the mesoscale conditions change.

This rainrate product can be updated globally once every 30 minutes and more frequently with GOES-8/10 data in some areas. The refresh rate is crucial to creating rain accumulations that would not be feasible with passive microwave data only due to the limited swath. Accumulations are very important to hydrologists for flash flood applications and average rainrates over 6-hour timeframes are the preferred numerical model input parameter.

The rainrate product in Figure 3 reveals the instantaneous rainrate for the western Pacific on 29 Sept. 1999. The use of collocated GMS-5 and passive microwave data make this product possible on an hourly basis. True diurnal variations can thus be sampled while this is not feasible with passive microwave data alone. The 28-km resolution of the inherent product also has many mesoscale rainrate applications ranging from nowcasting, flash flood warnings and initialization and validation of numerical prediction models.

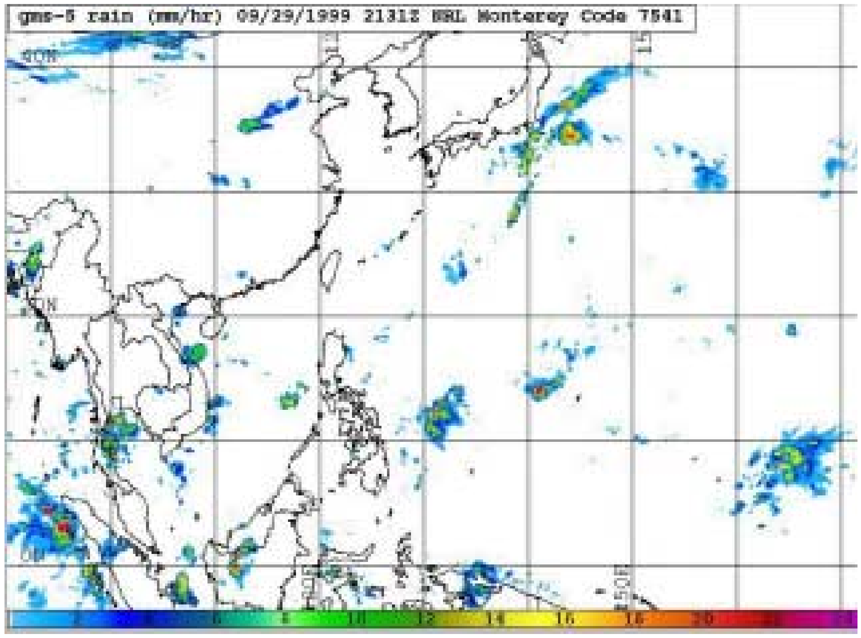

Figure 3. Rainrate product for portion of western Pacific created by combining passive microwave and geostationary IR data sets. Instantaneous rainrates (mm/hr) are displayed for the western Pacific, including a major piece of Asia and associated islands. Near real-time examples can be accessed via the NRL-MRY web page.

Passive microwave data can provide a wealth of information about the atmospheric water vapor as well as surface wind speed values. Figure 4 illustrates these capabilities while displaying geostationary IR and water vapor images for comparison. The top left panel is a enhanced IR image showing the vigorous cold frontal passage east of Japan. Strong cloud streaks can be seen near Japan and high surface winds can be assumed, but no quantitative information can be gleaned from this image. The lower left panel is a false colored image of the SSM/I surface wind speeds. The user can quickly detect the regions of high winds associated with the front and particularly the gap winds. The funneling of winds in mountain gaps is shown both on the China shoreline and also in several places along Japan's east coast. SSM/I surface winds can help supplement scatterometer-derived values and provide temporal sampling that is needed in nowcasting.

Total integrated water vapor can be very accurately derived via the SSM/I and an example is shown in the bottom right panel. Small, dry values are evident behind the cold front as expected. This is in stark contrast to the water vapor image in the upper right-hand panel. The water vapor imagery is sensitive to vapor aloft (e.g., 150-400 mb) and thus provides the analyst with no information about the lower levels. Use of both these tools can provide the forecaster with a better comprehension of the overall meteorological conditions.

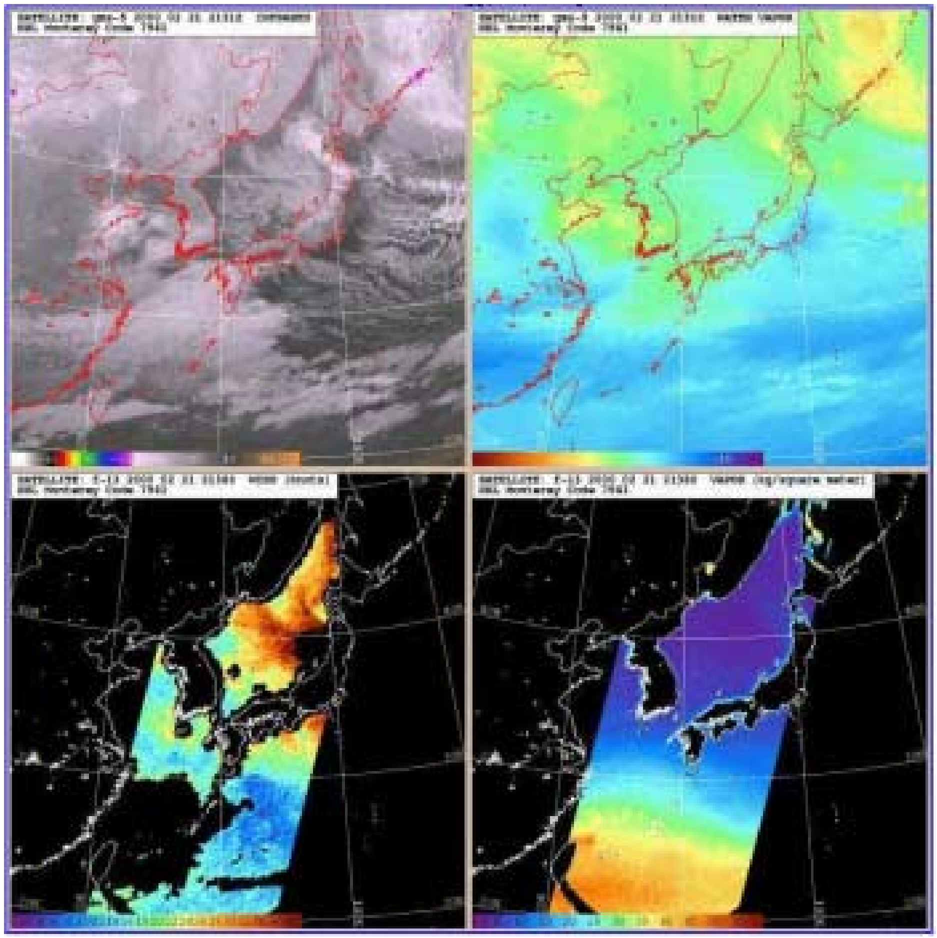

Figure 4: Comparison of geostationary IR (upper left panel), upper-level water vapor (upper right panel), SSM/I surface wind speeds (lower left panel), and SSM/I total integrated columnar water (lower right panel). All data is coregistered and within 30 minutes of each other.

3. CONCLUSIONS AND RECOMMENDATIONS

Multi-sensor satellite products must be used in order to take advantage of inherent spectral and sampling characteristics that meet specific Navy and DoD requirements. The coregistration of geostationary and polar orbiter data is essential for the successful creation and testing of new and improved products for the warfighter and opens areas for technology transfer to the civilian community. The NRL-MRY satellite meteorology application web page will continue to incorporate new and improved sensor data sets as they come online.

Various portions of the NRL-MRY satellite web page will be transitioned to operational Navy centers over the next few years. These successes will be due in part to the feedback made possible via hosting the real-time products on the Internet. The feedback has and will continue to be crucial to advancing the product suite to meet the changing needs of the user. In addition, the ability of the user to interact with the developers throughout the evaluation process has been instrumental in their success and acceptance once they are transitioned to operations.

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