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4B.4

HURRICANE SATELLITE (HURSAT) DATA SETS: LOW EARTH ORBIT INFRARED AND MICROWAVE DATA

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1. INTRODUCTION

Given the recent hypotheses relating long-term trends in tropical cyclone (TC) activity and global warming, there is a growing need for consistent reanalyses of the historical TC data. The hurricane satellite (HURSAT) data set provides a basis for consistent analysis. The HURSAT objective is to provide climate-calibrated satellite data to as wide a user base as possible for tropical cyclone research.

The initial version of HURSAT-B1 data provided 3-hourly observations centered on global tropical cyclones with ~8km spatial resolution (Knapp and Kossin, 2007). This data was used to perform a re-analysis of tropical cyclone intensities during 1983-2005 (Kossin et al., 2007). However, more information on tropical storms is available from other satellite instruments. In particular, the Advanced Very High Resolution Radiometer (AVHRR) provides finer spatial resolution and the Special Sensing Microwave Imager (SSMI) provides information on atmospheric structure below the cloud top. The characteristics of each data set are summarized in Table 1.

All HURSAT data are provided in NetCDF format. This allows users with experience in nearly any programming language to work with the data. The data are stored according to the Climate and Forecasting (CF) netCDF convention, which means that many software (e.g., IDV and GrADS) can read and process the data directly.

2.HURSAT-AVHRR

As opposed to the HURSAT-B1 data which originate from a collection of 29 geostationary satellites from 4 operating agencies, AVHRR data originate from an instrument which has undergone few changes during the period of record: 1978-present. Also, the AVHRR provides information on all tropical cyclones worldwide since its sun-synchronous polar orbit allows each spot on the Earth to be seen at least twice daily. In light of the gap in the geostationary satellite coverage over the Indian Ocean until 1998, this is a significant improvement. Also, the AVHRR Global Area Coverage (GAC) data have a 4km spatial resolution. This is twice the resolution of the HURSAT-B1, allowing for more detailed observations of tropical cyclones with small eyes. Thus, the 4km resolution will allow direct application of the Dvorak technique.

Given the above advantages, NOAA's National Climatic Data Center (NCDC) has begun the process to obtain all AVHRR observations of every tropical cyclone worldwide from the AVHRR period of record. So far, nine years have been processed (1978-1982 and 2002-2005) with the entire period of record to be processed soon.

Landsea et al. (2006) hypothesize that subjective measurements and variable procedures lead to biases in the tropical cyclone intensity record. They support this by showing AVHRR imagery for 5 tropical cyclones in the Indian Ocean which could be classified as major hurricanes, but were not at the time classified as being that intense. Three of the cyclones shown by Landsea et al. (2006) are reproduced in Figure 1. The corresponding images from HURSAT-AVHRR are provided in Figure 2. The similarity between Figures 1 and 2 demonstrates that the HURSAT-AVHRR accurately replicate observations from other sources. However, the HURSAT-AVHRR data provide the ability to analyze Basic Dvorak imagery anytime during the lifetime of each cyclone. (as provided in the links below Figure 2). Thus, HURSAT-AVHRR can be used to test the hypothesis of Landsea et al. (2006) by allowing one to analyze the entire HURSAT-AVHRR period of record (1978 to present) using either the original Dvorak Technique based on estimates from analysts or the Objective Dvorak Technique (Velden et al., 1998) based on estimates from computers.

3. HURSAT-MW: SSMI MICROWAVE DATA

The HURSAT-B1 and HURSAT-AVHRR data sets are limited in their sampling of tropical cyclones to the top of the cloud. But since clouds are more transparent at microwave wavelengths, a HURSAT data set using

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microwave data could provide information on the structure of the storm below the cloud top, such as identifying eye walls beneath central dense overcast. Such historical information could be useful in a reanalysis of tropical cyclones.

Tropical cyclone-related microwave data sets exist, but are incomplete. The Navy Research Laboratory archive[1] of microwave imagery begins in 1997 and is limited to JPG imagery so no remapping or quantitative analysis is possible. The Statistical Hurricane Intensity Prediction Scheme-Microwave Imagery (SHIPS-MI) data set (Jones et al., 2006) begins in 1995 and, like HURSAT, is provided on a storm-centric basis where the data grid follows the center of circulation.

The HURSAT-Microwave (MW) data derive from the Special Sensing Microwave Imager (SSMI) aboard the Defense Meteorological Satellite Program (DMSP) series of satellites was first flown in 1987. Like HURSAT-B1 and AVHRR, in HURSAT-MW, all SSMI channels are remapped to a fixed latitude-longitude grid for ease of analysis and display. The data are mapped to 8km to facilitate matchups with HURSAT-B1 data. However, the brightness temperatures are also provided in the original satellite swaths without remapping. HURSAT-MW data are available[2] from SSMI data spanning 1993-2006, and will soon be extended to the entire SSMI period of record (1987-present).

A sample of geophysical parameters available from the HURSAT-MW data are provided in Figure 3 for 1993 Hurricane Emily: column water vapor (Alishouse et al., 1990), rain rate (Ferraro and Marks, 1995), cloud liquid water (Weng and Grody, 1994) and sea surface wind speed (Goodberlet et al., 1990). The supplemental IR image is from the coincident HURSAT-B1 image. Similar to AVHRR, a link is provided showing the animation of the entire lifetime of Emily. Similar imagery for all storms during the HURSAT-MW period of record are available at the HURSAT website[2].

4. HURSAT-BASIN: GRIDDED GEOSTATIONARY DATA

Finally, another form of HURSAT data which are derived from the International Satellite Cloud Climatology Project (ISCCP) B1 is available from NCDC: HURSAT-Basin. The data are gridded at 8km and rather than following a tropical cyclone (like HURSAT-B1), the grids are static and span oceanic basin where tropical cyclones generally occur. This allows numerical analysis of regions of tropical cyclone development and decay. The purpose is to allow researchers the option to investigate regions and times not available through HURSAT-B1. This could include studying:

- Basin-wide statistics (e.g., using Hovmöller plots),
- Cyclogenesis (by studying regions where storms form as well as studying storms before they form, i.e., before they are observed in the HURSAT-B1 record), and
- Searching for missing storms.

NOAA's NCDC is also working on inter-calibrating the water vapour channels of the geostationary satellites to provide climate quality water vapor data in addition to the infrared window channel already available.

A beta version of the HURSAT-Basin data is available and being used by the tropical community (e.g., Douglas et al., 2008: Helms et al., 2008). The distribution of available basins is provided in Figure 4. A sample image from 1994 in the Western Pacific is provided in Figure 5 showing two tropical cyclones prior to merging (a link to a GIF loop is also provided). Researchers requiring data outside the seven regional basins can also obtain data from the "ALL" data set, which are the same data but gridded to a global 8-km (60° South to 60° North).

5. SUMMARY

The HURSAT series of satellite data sets have already aided tropical cyclone researchers and will provide a resource for hurricane and climate research. There is much information yet to be mined from this data source.

The complete period of record for the HURSAT-AVHRR and HURSAT-Basin will be available shortly and will be updated annually. Also, it may be possible to incorporate other satellite instruments into the HURSAT data set, such as the Advanced Microwave Sounding Unit (AMSU).

Future work will make use of the NCDC Global Tropical Cyclone Stewardship project (Kruk et al., 2008), which strives to merge best track data from the all available best tracks. Since the current HURSAT data use best track data from only the Joint Typhoon Warning Center (JTWC) and the Hurricane Database

[1] http://www.nrlmry.navy.mil/tc_pages/
[2] http://www.ncdc.noaa.gov/oa/rsad/hursat/

(HURDAT), this means that more storms will be included than presently available through HURSAT storm-centric (i.e., B1, AVHRR, and Microwave) data sets.

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Table 1 - Summary of various HURSAT products.

Product	**HURSAT-B1**	**HURSAT-AVHRR**	**HURSAT-MW**	**HURSAT-Basin**
Temporal span	1978-present	1978-present	1993-present	1978-present
Spatial span	Storm-centric: 10.5° from center for all global TCs	Storm-centric: 10.5° from storm for all global TCs	Storm-centric: 10.5° from center for all global TCs	Basin wide
Temporal resolution	3 hourly	Varying (6-12 hourly)	Varying (6-12 hourly)	3 hourly
Gridding resolution	8km	4km	8km[iii]	8km
Data source	ISCCP B1	AVHRR GAC	DMSP SSM/I	ISCCP B1
Channels available[iv]	IRWIN (11µm) IRWVP (6.7µm) VIS (0.65µm)	All AVHRR channels	All SSM/I channels	IRWIN (11µm) IRWVP (6.7µm) VIS (0.65µm)
Calibration	Clim.[v] – IRWIN, ISCCP – IRWVP, VIS	Climate calibrated.	Operational calibration.	Clim. – IRWIN, ISCCP – IRWVP, VIS
Yearly Size (GB)	<6.5	40-60	4	<20
Format	NetCDF	NetCDF	NetCDF	NetCDF
Current Version	3.0	Beta	Beta	Beta
Imagery	Movies[vi]	BD Imagery	Imagery[vii]	Planned

[iii] While the original SSMI data have a coarse resolution (ranging from 25-70km), the SSM/I gridded data are remapped to a resolution identical to the B1 for ease of display and analysis. However, the original SSM/I swaths are provided for further quantitative analysis. The swath data have various footprint sizes and two native sampling resolutions (referred to as the A and B scans).

[iv] IRWIN = Infrared Window, IRWVP = Infrared Water Vapor and VIS = visible channels.

[v] "Clim." and "climate" refers to a climate quality re-calibration. In the case of B1 data, a reanalysis of the ISCCP calibration using an independent instrument as a reference. For AVHRR, it relies on the work performed at NOAA/STAR. "ISCCP" refers to the absolute calibration provided by ISCCP.

[vi] http://www.ncdc.noaa.gov/oa/rsad/hursat/movie.php

[vii] http://www.ncdc.noaa.gov/oa/rsad/hursat/index.php?name=mw-imagery

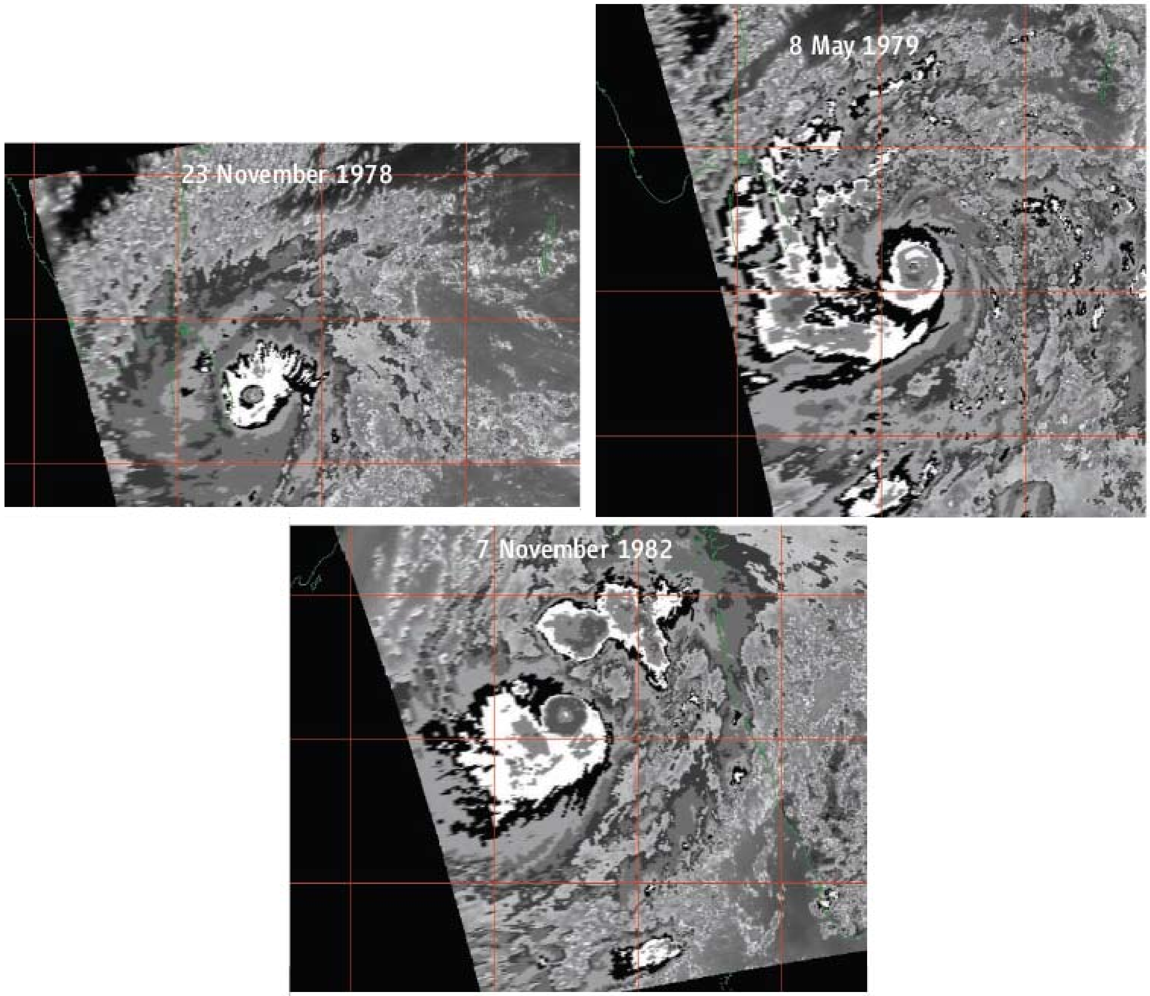

Figure 1 – Reproduction of figures from Landsea et al. (2006) showing three tropical cyclones in the Indian Ocean whose best track record may under-estimate their actual intensity (based on a reanalysis using the Dvorak Technique)

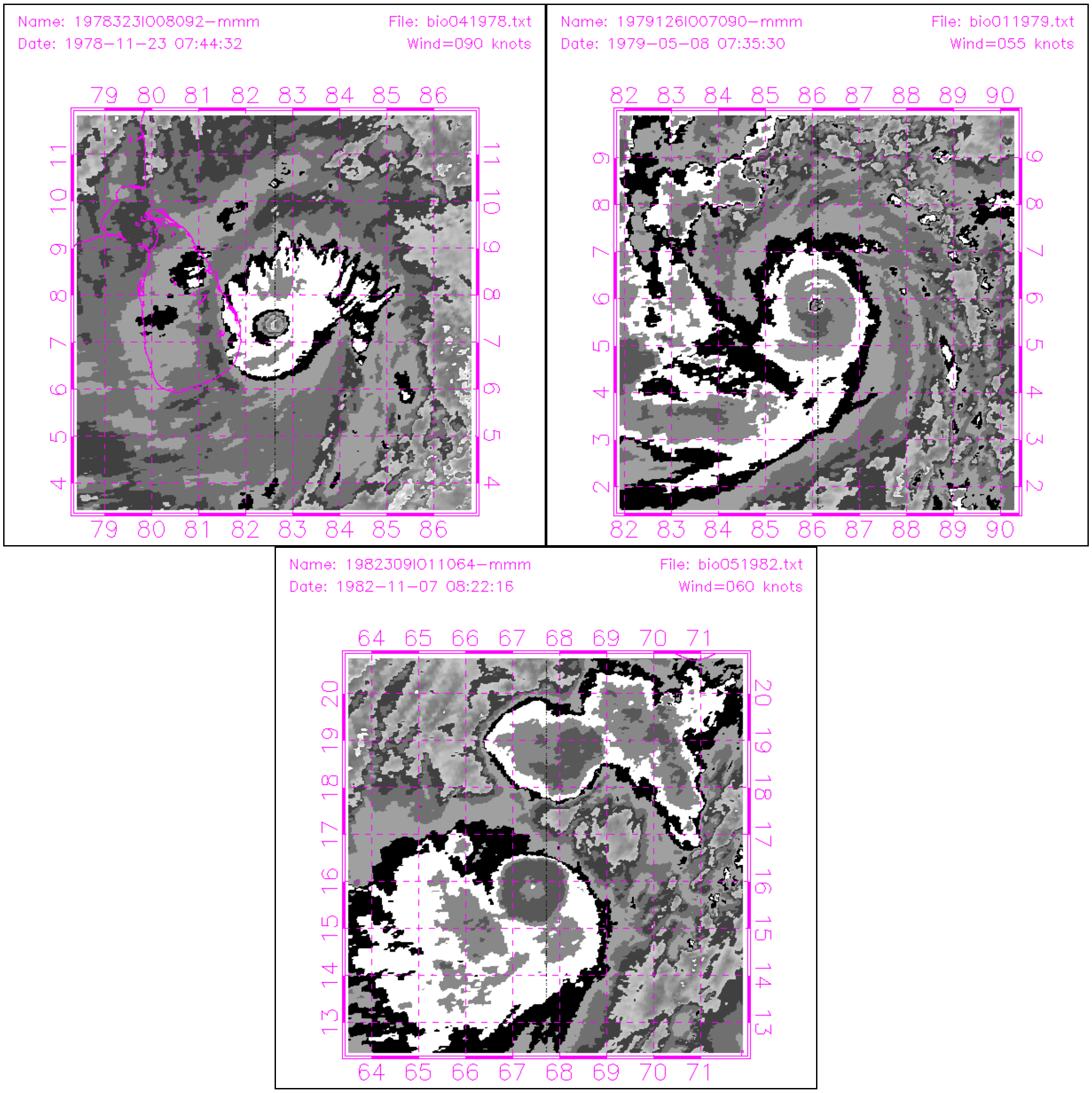

Figure 2 - HURSAT-AVHRR Imagery for the imagery in Figure 1. The HURSAT-AVHRR data captures the storms described in Landsea et al. (2006), providing netCDF files and BD imagery for the lifetime of each storm. GIF loops for each storm are available via the following links:

ftp://eclipse.ncdc.noaa.gov/pub/hursat/paper/1978323IO08092-mmm.gif
ftp://eclipse.ncdc.noaa.gov/pub/hursat/paper/1979126IO07090-mmm.gif
ftp://eclipse.ncdc.noaa.gov/pub/hursat/paper/1982309IO11064-mmm.gif

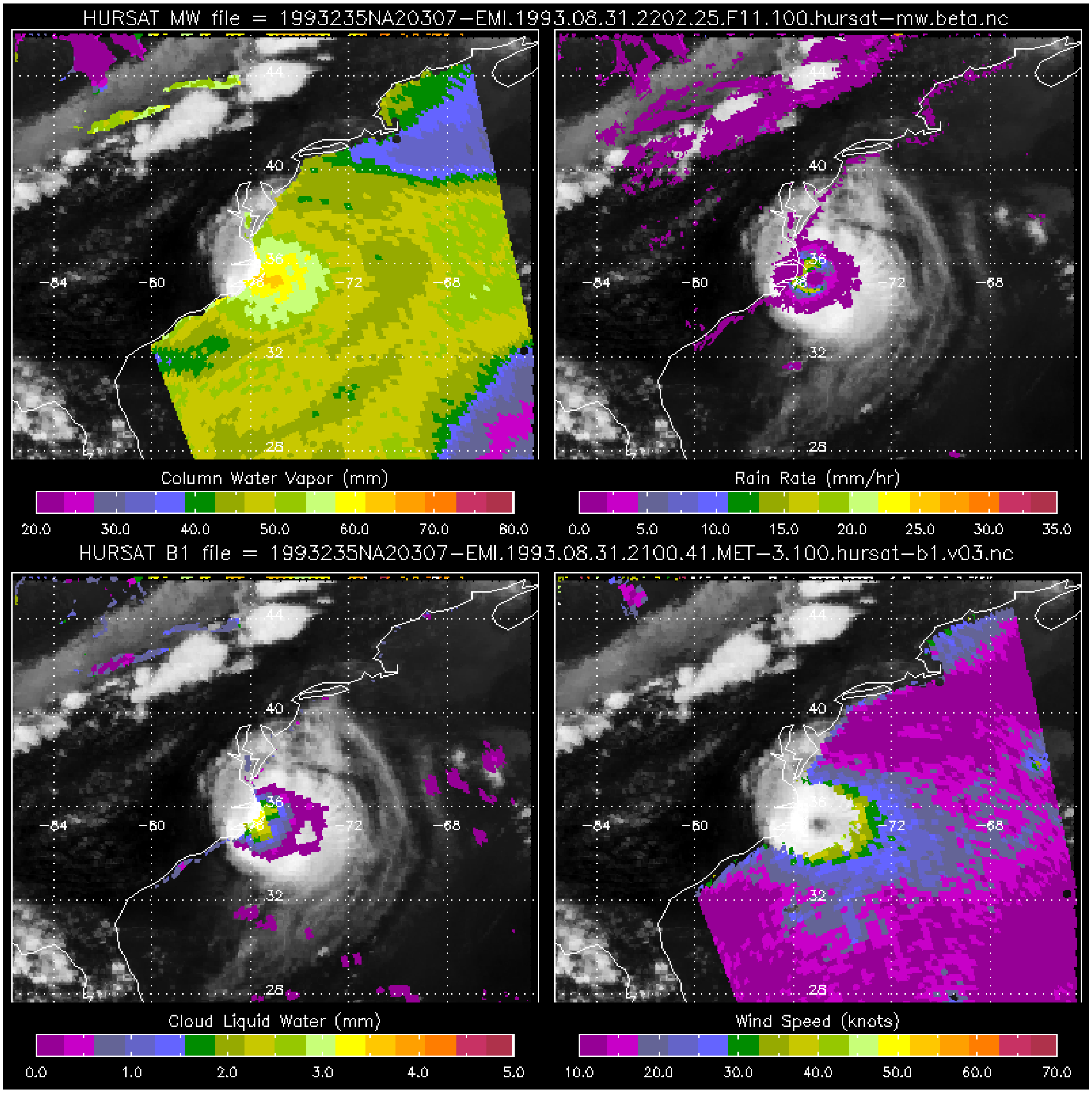

Figure 3 - Example of products possible with the HURSAT-MW data. The data are column water vapor, rain rate, cloud liquid water and sea surface wind speed as derived from the HURSAT-MW for Hurricane Emily as it made landfall on North Carolina in 1993. A loop of all HURSAT-MW data for Hurricane Emily is available at:

ftp://eclipse.ncdc.noaa.gov/pub/hursat/paper/1993-Emily.gif

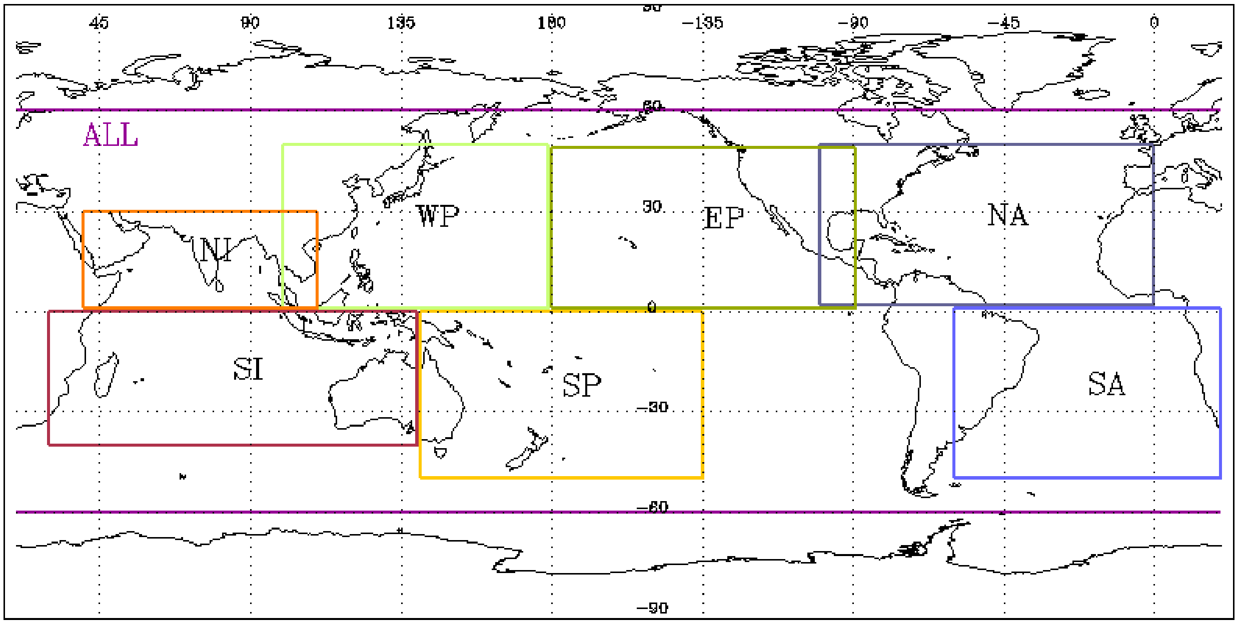

Figure 4 – Bounding latitudes and longitudes for the basins available thorugh HURSAT-Basin: NA North Atlantic), EP (Eastern Pacific), WP (Western Pacific), NI (North Indian), SI (South Indian) and SP (South Pacific) basins. Also, the ALL basin provides global data from 60°S to 60°N.

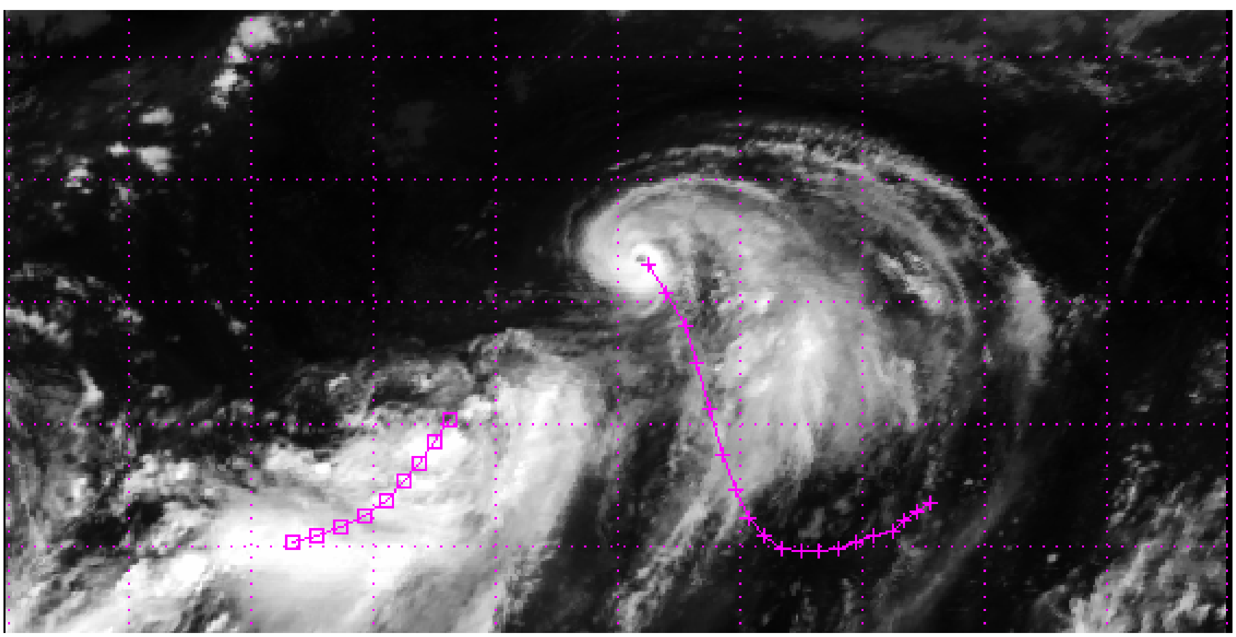

Figure 5 - Sample imagery from HURSAT-Basin during the merger of two tropical cyclones in the Western North Pacific Ocean. A loop showing the merger in its entirety is available at:

ftp://eclipse.ncdc.noaa.gov/pub/hursat/paper/Storm-Merger.gif