

Hurricane Satellite (HURSAT) data sets: Development, access and applications

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Abstract

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. Recent work at NCDC has developed satellite based, tropical cyclone-centric data sets. This document highlights current and future work at NCDC to develop hurricane satellite (HURSAT) data sets.

HURSAT DEVELOPMENT

The HURSAT data set began as a collaborative project between NCDC and the University of Wisconsin to provide an objective reanalysis of tropical cyclone intensity (Kossin, et al. 2007). The result was HURSAT-B1: a set of tropical cyclone observations from geostationary satellites around the world at 3-hourly and 10-km resolution spanning 1983 to 2005 (Knapp and Kossin 2007). Since then, the HURSAT-B1 data span has been expanded to include historical data (as early as 1978 for the Atlantic basin) and recent years (currently through 2006).

NCDC maintains archives of other satellite data useful for tropical cyclone research. Data from NOAA's Polar Orbiting Environmental Satellites (POES) Advanced Very High Resolution Radiometer (AVHRR) and the Defense Meteorological Satellites Program (DMSP) Special Sensing Microwave Imager (SSM/I) are two which can be used to better understand tropical cyclones. The following summarizes the HURSAT-B1 data set and how HURSAT data from other satellites provide more information on tropical cyclones.

HURSAT-B1

Details on HURSAT-B1 data are provided on the Internetⁱ and in Knapp and Kossin (2007), so only a short summary is given. The satellite data for HURSAT-B1 are the B1 level of sampled satellite data from the International Satellite Cloud Climatology Project (ISCCP) described on the Internetⁱⁱ and by Knapp and Bates (2004). In short, B1 data from all meteorological geostationary imagers are available 8 times per day (optimally at 3-hour intervals near the synoptic hours of 00, 03, ..., 21 UTC). The imagery is sub-sampled to approximately 8 km and has been archived at NCDC since 1983. Recent data rescue efforts at NCDC have made this data available and expanded the original period of record back to the 1970s (Knapp, et al. 2007). The spatial distribution of satellites in time is shown in Figure 1.

Significant effort went into making the ISCCP-B1 data, and hence HURSAT-B1, temporally consistent. NCDC checked the ISCCP inter-calibration using HIRS data and found an anomaly in 2001 which was attributed to an error in the ISCCP inter-satellite normalization (Knapp 2008). The corrected observations were then used to estimate tropical cyclone intensity by Kossin et al. (2007).

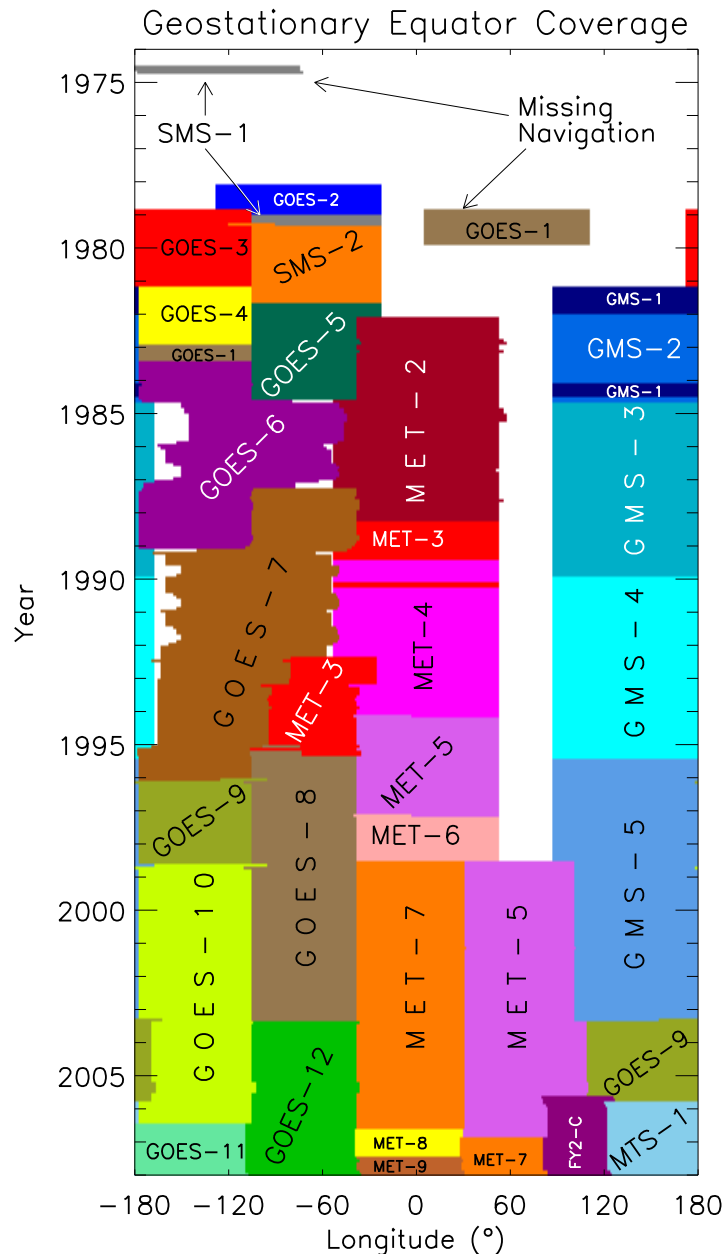


Figure 1 - Spatial and temporal coverage of geostationary imagers for the ISCCP B1 period of record. While data exist for SMS-1 in 1974 and GOES-1 in 1979, there are no navigation parameters allowing the data to be gridded. Thus, the effective start date for HURSAT-B1 is GOES-2 in 1978.

BASIN-WIDE OBSERVATIONS

Using the same calibration and gridding resolution as HURSAT-B1, HURSAT-Basin provides satellite observations of entire tropical basins. The purpose is to allow researchers the option of investigating regions and times not available through HURSAT-B1. This could include studying:

- Basin-wide statistics,
- 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.

NCDC is also working on inter-calibrating the water vapour channels of the geostationary satellites to provide a climate quality water vapour data in addition to the infrared window channel already available. More details of the HURSAT-Basin data are provided in Table 1. A beta version of the HURSAT-Basin data is already available.

Product	HURSAT-B1	HURSAT-Basin	HURSAT-MW	HURSAT-AVHRR
Period of record	1978-present	1978-present	1987-present	1979-present
Spatial span	10.5° from storm center for all global TCs	Basin wide ~100° long ~50° lat.	10.5° from storm center for all global TCs	10.5° from storm center for all global TCs
Temporal resolution	3 hourly	3 hourly	Varying	Varying
Gridding resolution	8km	8km	8km ^{III}	4km
Based on ...	ISCCP B1	ISCCP B1	DMSP SSM/I	AVHRR GAC
Channels available ^{IV}	IRWIN (11µm) IRWVP (6.7µm) VIS (0.65µm)	IRWIN (11µm) IRWVP (6.7µm) VIS (0.65µm)	All SSM/I channels	All AVHRR channels
Calibration	Clim. ^V - IRWIN. ISCCP – IRWVP, VIS	Clim. - IRWIN. ISCCP – IRWVP, VIS	Operational calibration.	Climate calibrated.
Yearly size (GB)	<6.5	<20	4	40
Format	NetCDF	NetCDF	NetCDF	NetCDF
Current Version	2.1	Beta	Beta	Beta
Movies	Available	Planned	None	None

Table 1: Summary of details for various existing and proposed HURSAT products.

OBSERVATIONS FROM AVHRR

The AVHRR provides a unique perspective in observing historical tropical cyclones which generally complement the HURSAT B1 data set.

A limitation to the HURSAT-B1 and Basin data sets is the spatial resolution, which is 8 km. This size is unable to detect very small eyes of intense tropical cyclones. Due to this limitation, it is not advised to use this algorithm with the objective Dvorak technique (ODT) (Chris Velden, personal communication, 2007). However, AVHRR GAC (Global Area Coverage) data have a spatial resolution of 4km. This corresponds to the intended spatial resolution of the ODT. Thus, HURSAT data from AVHRR can be used in an objective analysis with tools that have already been developed and tested.

The inter-calibration of ISCCP B1 data is complicated by the number of instruments and data providers. In contrast, the AVHRR has remained a relatively stable instrument (i.e., similar sensor channels on each satellite) in polar orbit.

The polar orbit provides global coverage for AVHRR. In contrast, the Indian Ocean is poorly sampled prior to 1998 from geostationary orbit (as far as data is available in the ISCCP 1 record). This is not the case with AVHRR which provides at least twice daily observations of the entire globe. In fact, the number of daily observations is roughly twice the number of satellites operating allowing for as many as 6 daily observations, for example, during Hurricane Katrina in 2005.

However, the number of daily observations for a storm never reaches the level of HURSAT-B1, which provides 8 observations per day from a smoothly-changing satellite view angle. Conversely, the daily drift of the polar-orbit, combined with the storm motion, means that cyclones may not be well-sampled on a daily basis (that is, a storm may be at satellite nadir while during the next, it could be on the edge of the swath).

The above highlights some of the differences between HURSAT-B1 and a proposed HURSAT-AVHRR. More differences exist and some details are provided in Table 1. It is expected that a beta version of the HURSAT-AVHRR data will become available during 2007.

OBSERVATIONS FROM MICROWAVE IMAGERS

The HURSAT-B1 and HURSAT-AVHRR data sets are limited in their sampling of tropical cyclones to the top of the cloud in any given pixel. Conversely, clouds are more transparent at microwave wavelengths. Thus, a HURSAT data set using microwave data can provide information on the structure of the storm below the cloud top, such as estimating cloud liquid water, column water vapour and rain rate. Such historical information will prove useful in a reanalysis of tropical cyclones.

The SSM/I aboard the DMSP series of satellites was first flown in 1987. It is expected that a beta version of the HURSAT-microwave data for SSM/I will be available in 2007. The data will be remapped to a fixed latitude-longitude grid for ease of analysis and display. However, the brightness temperatures will also be provided in the original satellite swaths for further quantitative calculations.

SUMMARY AND FUTURE WORK

The HURSAT data set provides tropical-cyclone-centric data, thereby facilitating tropical cyclone research. The data provide information for research relevant to forecasting (e.g., storm structure, formation, and cyclogenesis) as well as longer term studies (trends in storm intensity, etc.). Future work will be to develop complete climate quality observations from the instruments described above. Additionally, more work could be performed, for example, to subset the full resolution geostationary data which can provide higher spatial and temporal resolutions than the HURSAT-B1. Given the impact of tropical cyclones on society, the importance of the HURSAT data set is only just beginning to be realized.

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ⁱ HURSAT data are described at <http://www.ncdc.noaa.gov/oa/rsad/hursat/>.

ⁱⁱ ISCCP B1 data are described at <http://www.ncdc.noaa.gov/oa/rsad/isccpb1/>.

ⁱⁱⁱ In the netCDF files, the SSM/I swaths with the original earth locations are provided in addition to the gridded SSM/I data. For ease of display and analysis, the SSM/I gridded data are remapped to a resolution identical to the B1. However, for further quantitative analysis, the original satellite swath data are also provided in the netCDF files, which 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.