P4.20

Introducing the Operational GOES Imager Clear-Sky Brightness Temperature (CSBT) Data Products

Anthony J. Schreiner[1]
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Madison, WI 53706

James A. Jung
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Madison, WI 53706

Timothy J. Schmit
NOAA/NESDIS, Office of Research and Applications
Advanced Satellite Products Team (ASPT)
Madison, WI 53706

Curtis W. Holland
NOAA/NESDIS, Office of Satellite Data Processing and Distribution
Camp Springs, MD 20746

James P. Nelson III
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Madison, WI 53706

Timothy L. Olander
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Madison, WI 53706

W. P. Menzel
NOAA/NESDIS, Office of Research and Applications
Madison, WI 53706

ABSTRACT

A new satellite-derived product, called the Clear-Sky Brightness Temperature (CSBT), based on Geostationary Operational Environmental Satellite (GOES) Imager radiance data, was requested by National Centers for Environmental Prediction (NCEP)/ Environmental Modeling Center (EMC) and the European Centre for Medium-range Weather Forecasts (ECMWF) for assimilation into global weather prediction models to better analyze the initial atmospheric state.

The National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS)/Office of Research and Applications (ORA), together with the Cooperative Institute for Meteorological Satellite Studies (CIMSS), has developed software to select cloud-free Fields-Of-View (FOVs), average these data to 50 km by 50 km areas, and stage the information to Binary Universal Format Representation (BUFR) files for subsequent use by the modeling community. The CSBT product provides clear sky information for the five spectral bands from both the GOES-East and –West Imagers. Since early November 2001, CIMSS has produced hourly, hemispheric coverage of these data. NCEP and ECMWF have successfully accessed and decoded the CSBT data and

[1] *Corresponding author address*: Anthony J. Schreiner, SSEC, 1225 West Dayton Street, Madison, WI 53706; email: Tony.Schreiner@ssec.wisc.edu.

routinely incorporated them into their databases. After tests that showed positive impact, ECMWF has been operationally using these data from the water vapor channel (band 3, 6.5/6.7 um) since 7 Oct 2003 for GOES-12 (East), -10 (West), and –9 (western Pacific). NCEP has taken an initial look at the data. Furthermore, the NOAA/NESDIS/ Office of Satellite Data Processing and Distribution (OSDPD) has recently incorporated the CSBT processing system for GOES-10 and -12 into their operational suite of products.

Assimilation of geostationary satellite data allows a more complete description of the atmosphere for initialization of numerical weather analyses and forecasts by providing hourly radiance information. The current GOES Imagers provide information on upper-level tropospheric humidity structures (water vapor channel), the surface temperature, and near surface humidity (window channels). Compared to polar orbiting satellites, the benefit of geostationary imagers comes from the high temporal frequency (hourly) of radiance observations and increased areal coverage.

Coverage for the GOES East and West CSBT product extends from roughly 67S to 67N and 30W to 165E. For each 50 km processing box the average brightness temperature for each infrared (IR) band is calculated along with the average clear and cloudy brightness temperatures. Processing is performed using the Man computer Interactive Access System (McIDAS) and the output information is then transferred from a McIDAS Meteorological Data (MD) file into a BUFR file. Data are available via anonymous file transfer protocol (ftp).

1. INTRODUCTION

Since November 2001, the CIMSS has been deriving CSBT information (Schreiner et al. 2003) from the GOES –8, -9, -10, and -12 Imagers (Menzel and Purdom 1994). Beginning in November 2005, operational processing was officially handed over to the OSDPD. This NOAA/NESDIS group is responsible for operational production of satellite derived products.

The CSBT data are then made available to the NCEP/EMC in Washington, D.C. and the ECMWF in England via ftp for assimilation into global weather prediction models. In order to take advantage of the diurnal capabilities of a geostationary platform, processing frequency is hourly and coverage is hemispheric. This product compliments the water vapor CSBT product from the European Meteorological Satellite (Meteosat) produced by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and assimilated operationally at ECMWF (Köpken et al. 2002 and Szyndel et al. 2005).

The purpose of this paper is to briefly describe the data coverage, both temporal and spatial; the technique for producing the output; and illustrate some preliminary results obtained by using these CSBT data in numerical weather forecasts. Future work is summarized in the final section.

2. DATA

Current coverage for the operational CSBT extends from roughly 67S to 67N and 30W to 165E for GOES -10, and -12. The data are averaged over boxes of approximately 50 km per side. Each box consists of 187 (eleven rows by seventeen columns) FOVs. For a given box a cloud detection algorithm (Schreiner et al. 2001) is used. This clear/cloudy algorithm involves comparisons of brightness temperatures with its neighbors, surface information provided by hourly observations where available, the NCEP Global Forecast System (GFS) model numerical forecasts, and remotely sensed Sea Surface Temperatures (SSTs) based on Advanced Very High Resolution Radiometer (AVHRR) observations. For each 50 km box the average brightness temperature for each infrared (IR) band and the albedo in percent for the visible band are calculated along with the average clear and cloudy brightness temperatures. Additional parameters determined are the number of clear and cloudy FOVs, center latitude and longitude of the box, center local zenith and solar zenith angles of the box, land/sea flag, standard deviation of the average clear and cloudy brightness temperatures, and two quality indicator flags. The quality indicator flags provide information on the likelihood of a particular observation being affected by sun glint and the relative quality of the SST observation.

3. PROCESSING SYSTEM

Processing is performed using the McIDAS (Young et al. 1998) and the output information is then transferred from a McIDAS MD file into a BUFR file. Data have been produced near hourly since 24 October 2001. Data latency is generally less than one hour (actual processing time is between 2 and 4 minutes), and the product is available approximately fifty minutes after the nominal start of the GOES -12 Imager image (hh:45:00).

Besides the averaged output data, single FOV information is also generated in the form of a McIDAS image or area file. Figure 1 is a composite image from the GOES-8 & -10 Imagers for the 11.0 μm (Long Wave Window) band for 23 September 2002 at 18 UTC. Figure 2 is the corresponding CSBT single FOV output image of the 11.0 μm (Long Wave Window) band for the GOES Imager The yellow to red colored portion of Figure 2 shows the clear FOV brightness temperatures. The "gray mask" denotes the cloudy FOVs. This single FOV product is useful in determining the effectiveness of the cloud detection algorithm.

Several quality control steps are performed during the CSBT retrieval process before these data are made available to the user community (in this case the "user community" are NCEP/EMC and ECMWF). These are described below.

First, in order to compensate for the degradation over time of the GOES Imager visible sensor, a correction based on the work of Bremer et al. (1998) was incorporated into the cloud detection technique. The correction assumes a linear degradation of the visible sensor beginning at the time of launch, and is based on research done with the GOES-8 & -9 Imagers. For CSBT processing the correction was applied to GOES-8, -9, -10, and -12, resulting in an improved capability of detecting low clouds during the day.

Secondly, an additional step was added in order to further edit "cloudy" FOVs from the 11x17 box per CSBT retrieval by adding a Gaussian fit parameter. This technique measures the distribution of the clear samples for each box. If the "Gaussian fit" is "bad" (i.e. there is a tail of cloud-contaminated FOVs along the cold side of the distribution), the sample is modified in order to remove the cloudy FOVs. An example of this technique is shown in Figure 3. The net affect of this correction is fewer clear FOVs per box and fewer clear boxes per time period. One additional effect is better coverage during nighttime hours.

Additional quality controls have been incorporated that are meant to allow the user some flexibility in deciding which CSBT observations to accept. These quality control flags are defined such that "0" equates to no effect (or "good"), whereas "100" equates to maximum effect (or "bad"). These quality flags include two potential sources of error: sun glint and sea surface temperature.

Because the visible band is heavily relied upon for the detection of cloud, especially low cloud during daytime hours, sun glint in the visible image near the equatorial region can be a source of error. It is possible to miss cloud that would normally be detected. In order to compensate for this potential shortcoming, a quality flag is provided that is based on the proximity of each CSBT observation to the location of maximum affect of the sun glint. The quality flag values range from 0 to 100, where 0 implies no affect due to sun glint and 100 is at the center of the sun glint location for a unique day and time.

There are two sources of surface temperature over the oceans. One source of surface temperature is based on a surface analysis composed of a few observations over the ocean and a numerical forecast. The second source of surface temperature is derived from remotely-sensed temperatures from the NOAA series of polar orbiters. Over water the cloud detection technique uses the remotely sensed SST. There are instances when the remotely-sensed and objectively analyzed SST values disagree significantly. When this occurs, the cloud masking algorithm will use the warmer of the two. To track this inconsistency, a confidence flag is introduced such that when the two values are equal the confidence flag is equal to 0. When the difference between the two values of sea surface temperature is greater than or equal to 10C, the confidence flag is set to 100.

The averaged CSBT are currently being collected, decoded, evaluated, and assimilated into global numerical weather prediction models at ECMWF. NCEP/EMC performed a preliminary evaluation of the GOES Imager CSBT and found the water vapor channel (band 3, 6.7 μm) to be of good quality. Additional quality control tests of the averaged CSBT for the infrared surface bands (band 2, 3.9 μm; band 4, 11.0 μm; band 5, 12.0 μm) by NCEP/EMC indicated some deficiencies in the cloud detection algorithm. One test demonstrated how cloudy FOVs were incorrectly being identified as clear. This deficiency was remedied, and the improved data were first made available on 1 July 2002. NCEP agreed that the IR Window band data was indeed better.

4. PRELIMINARY RESULTS

Assimilation experiments at the ECMWF have shown positive impact. Clear sky radiance data from both METEOSAT and GOES (providing near global coverage of hourly brightness temperatures) were used in these experiments. Graphical results of these experiments are shown in Figure 4. A significant portion of this work involved quality control of the remotely sensed observations. The end result led to an evolution of these products, where clear sky radiance data was able to provide a positive impact on forecast skill at ECMWF (Szyndel et al. 2005 and Köpken et al. 2003). In terms of 500 hPa geopotential heights, the forecast impact is positive at the 95% confidence level at six days, in both hemispheres. Furthermore, the impact of the assimilation of these data may be seen in the first guess departure statistics of HIRS channel 12, showing that the moisture field is being altered in a manner consistent with other instruments (not shown).

The quality of GOES Imager clear sky radiance data was evaluated and the quality control procedure was developed at NCEP/EMC using a previous version of the CSBT (Su et al. 2003). Experiments assimilating GOES clear sky radiance data were conducted from 1 – 30 September 2002. The impact of GOES Imager clear sky radiance data was evaluated. The verification results showed that the impact on mid-latitude geopotential height and tropical winds was close to neutral (slightly positive). However, the forecast precipitation scores in the US were slightly worse for higher rainfall amounts. Verification against rawinsonde observations showed that on average there was almost no impact on moisture and temperature fields over North and South America. Day-to-day comparisons show that most impacts occurred on the tropical moisture field and winds at higher levels. Re-evaluation of the latest version of the CSBT is being planned at NCEP.

NOAA/NESDIS and CIMSS have made efforts to improve data quality and add information to supplement the CSBT data. We plan to reexamine our data quality control procedures and the observation error assignments, based on new data variance information provided to NOAA/NESDIS and CIMSS by the numerical weather prediction centers.

5. FUTURE WORK

GOES-9 is scheduled to be brought offline during November 2005, and replaced with the new Japanese geostationary platform, Multi-functional Transport Satellite (MTSAT-1R). The GOES-9 CSBT product is an experimental product generated at CIMSS, and it is possible that the MTSAT geostationary satellite can replace the GOES-9 CSBT.

A more sophisticated algorithm to correct the GOES-10 and -12 visible sensor degradation has been developed by Wu and Sun (2005). There are plans to incorporate this new visible correction technique, which is unique to each of the GOES Imager platforms.

6. ACKNOWLEDGMENTS

The authors would like to thank Marine Bonazzo (ECMWF), Simon Elliot (WMO), Paula Freeman (NCEP), Dennis Keyser (NCEP), Christina Köpken (ECMWF), Robert Potash (OSDPD), Barry Roth (CIMSS), XiuJuan Su (NCEP), Matthew Szyndel (ECMWF), Deyong Xu (OSDPD), Thomas Achtor (CIMSS), and Steven Ackerman (CIMSS) for their help and support while preparing this product for operational production over the last four years. Funding for this work was provided by NOAA grant #NA07EC0676. The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. Government position, policy, or decision.

7. REFERENCES

Bremer, J.C., J.G. Baucom, H. Vu, M.P. Weinreb, N. Pinkin, 1998: Estimation of long-term throughput degradation of GOES-8 & -9 visible channels by statistical analysis of star measurements. Proc. SPIE, Vol 3439, 145-154.

Köpken, C., G. Kelly, and J.N. Thépaut, 2003: Assimilation of water vapor radiances from geostationary imagers in 4DVAR, To be presented at the 12th AMS Sat. Con., Feb., 2003.

Menzel, W.P. and J.F.W. Purdom, 1994: Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites, Bull. Am. Meteorol. Soc., **75**, 757-781.

Schreiner, A.J., T.J. Schmit, and W.P. Menzel, 2001: Observations and trends of clouds based on GOES sounder data. *Journal of Geophysical Research-Atmospheres*, **106**, 20,349-20,363.

Schreiner, A. J.,T. J. Schmit, C. Kopken, X. Su, C. Holland, and J. A. Jung, 2003: Introducing the GOES Imager clear-sky brightness temperature (CSBT) product. Preprints, *12th Conf. On Satellite Meteorology and Oceanography*, Long Beach, CA, Amer. Meteor. Soc.

Su, X., J.C. Derber, J.A. Jung, and Y. Tahara, 2003: The usage of GOES imager clear-sky brightness temperatures in the NCEP global data assimilation system. Preprints, *12th Conf. On Satellite Meteorology and Oceanography*, Long Beach, CA, Amer. Meteor. Soc.

Szyndel, M., J.-N. Thepaut, and G. Kelly, 2003: Developments in the assimilation of geostationary radiances at ECMWF. EUMETSAT/ECMWF Fellowship Programme, 1st Year Report, 25 pp.

Wu, X and F. Sun, 2005: Post-launch calibration of GOES imager visible channel using MODIS. 2005 Proceedings of SPIE Vol. 5882, Earth Observing Systems X, 31Jul – 2Aug 2005.

Young, J.T., T.M. Whittaker, M.A. Lazzara, and R.J. Fox, 1998: McIDAS – Its 25th anniversary. International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, 14th, Phoenix, AZ, 11-16 January 1998. Boston, MA, American Meteorological Society, 1998. pp24-30.

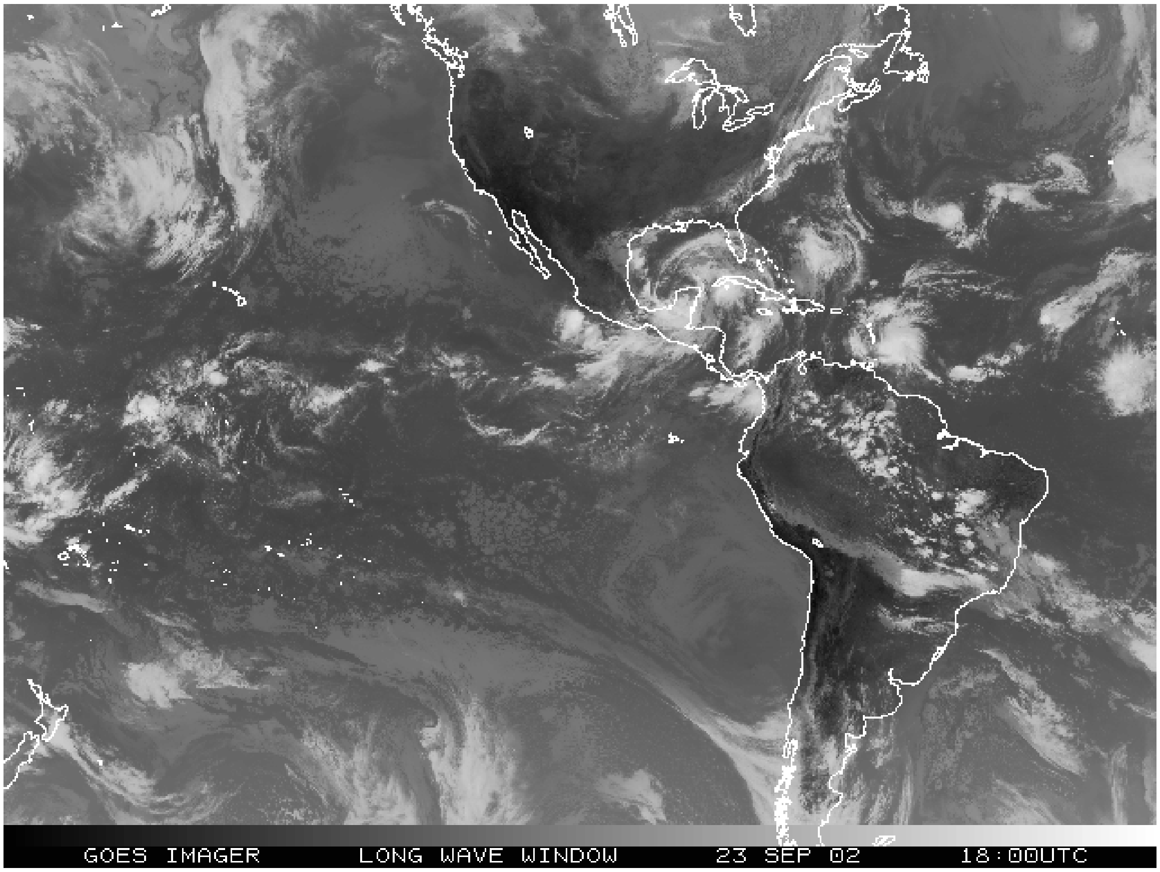

Figure 1. Combined GOES-8 & -10 Imager 11.0 μm (Long Wave Window) band for 12 March 2002 at 15 UTC.

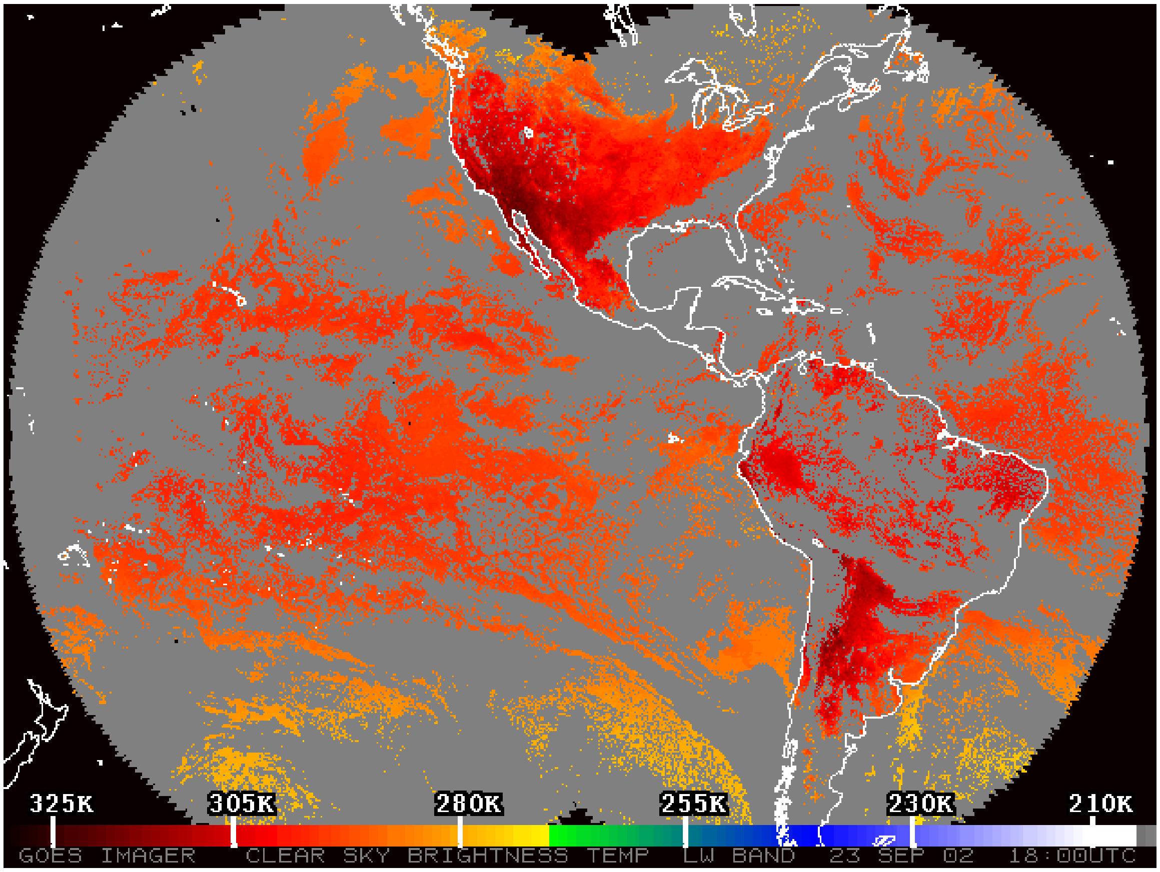

Figure 2. Combined GOES-8 & -10 Clear Sky Brightness Temperature image of the 11.0 μm (Long Wave Window) band for 12 March 2002 at 15 UTC. Grey indicates cloud and white through dark red indicate clear regions.

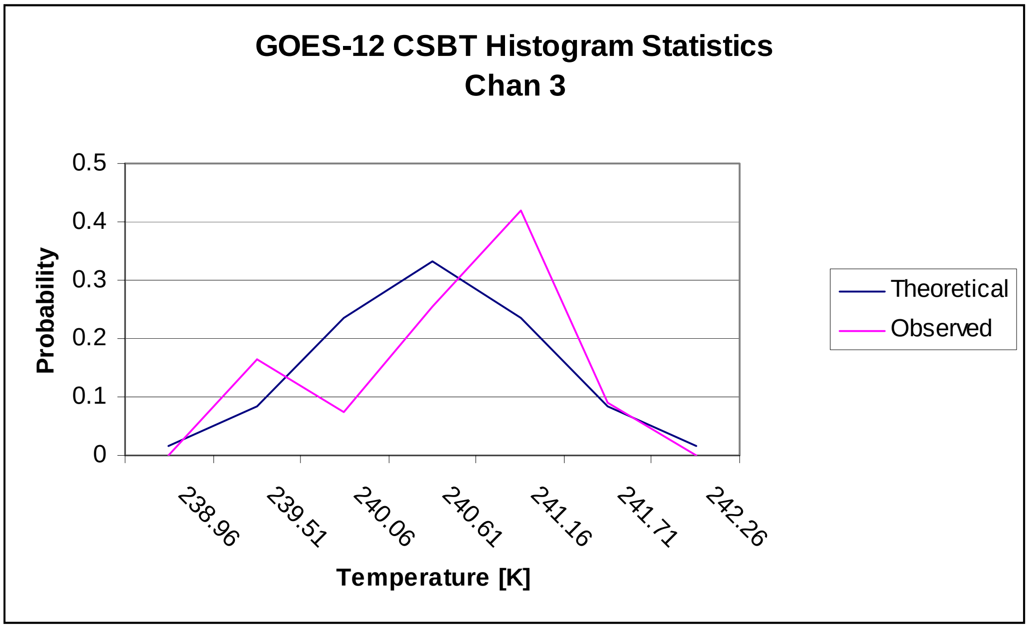

Figure 3A. Distribution of Observed (red) clear FOVs (N=67) before a "Gaussian fit" correction has been applied. Average Temperature for Band 3 (6.5µm) is 240.61K.

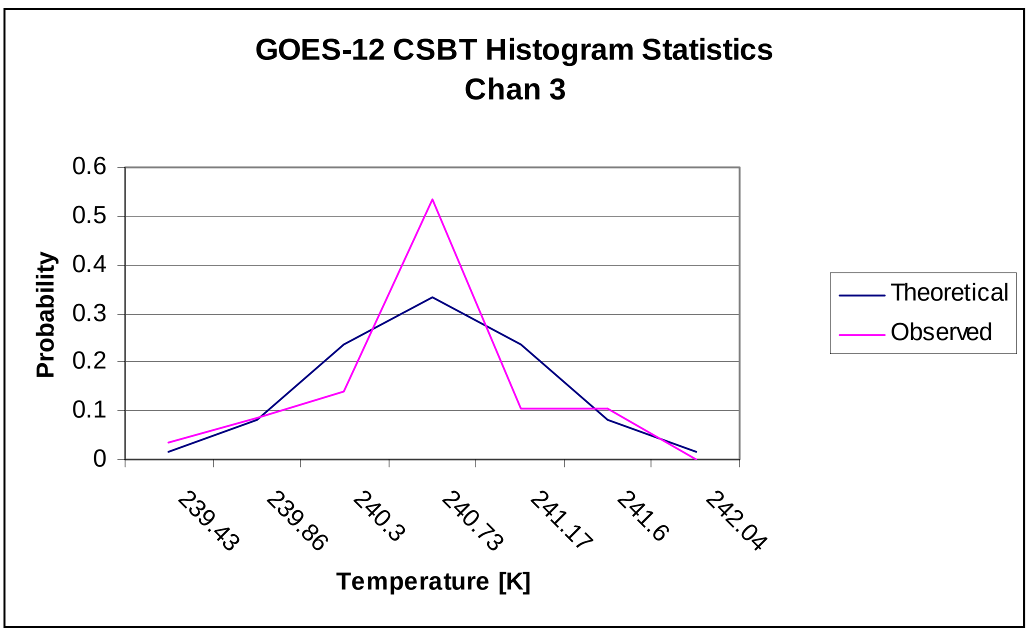

Figure 3B. Distribution of Observed (red) clear FOVs (N=50) after a "Gaussian fit" correction has been applied. Average Temperature for Band 3 (6. 5µm) is 240.73K.

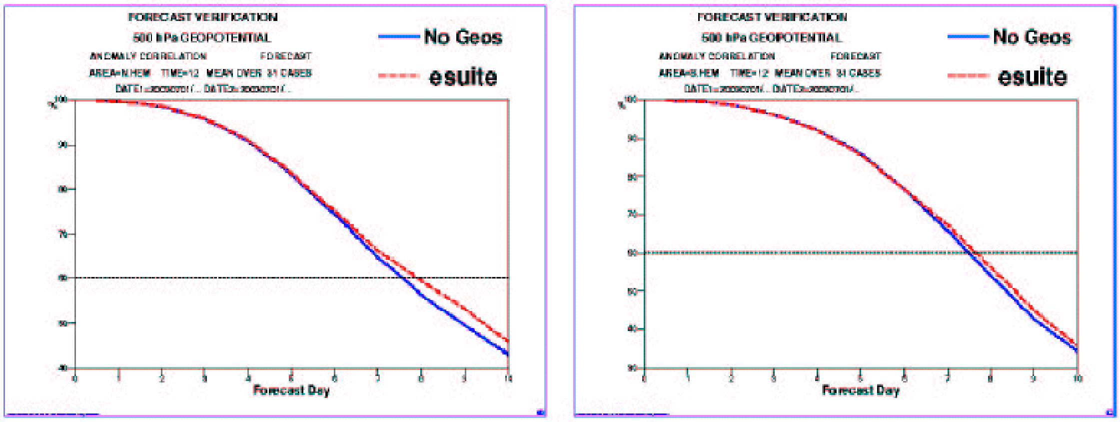

Figure 4. ECMWF global forecasts with geostationary satellite observed Clear Sky Brightness Temperatures (red) and without (blue) for the Northern Hemisphere (left) and the Southern Hemisphere (right). This figure shows that Infrared geostationary water vapor CSBT Imager data slightly improves global numerical model forecasts beyond 5 days, for both hemispheres. GOES-9/10/12 and Meteosat data were used. (From Szyndel et al. 2005.)