CGMSXXXUSA-WP-31
Agenda Item: II.3
Discussed in WG-2

# 2001 / 2002 Report on NOAA/NESDIS GOES Soundings

## Summary and Purpose of Document

This paper summarizes the current NOAA/NESDIS operational sounding product suite derived from the GOES sounder. Anticipated improvements under study are also summarized

## Action Requested: None

# 2001 / 2002 REPORT ON NOAA/NESDIS GOES SOUNDINGS

Timothy J. Schmit [1], W. Paul Menzel [1], Jaime Daniels [1],
Youri Plokhenko [2], James P. Nelson III [2], and Gail Bayler [2]

[1] - NOAA/NESDIS/ORA
[2] - Cooperative Institute for Meteorological Satellite Studies
Madison, Wisconsin

## 1. Introduction

The NOAA/NESDIS operational GOES-8/10 soundings continue to be produced every hour at approximately 50 km resolution (5X5 Fields of View (FOV) in clear skies (research retrievals are routinely generated at single FOV 10 km resolution). Operations is evolving to single FOV retrievals. Derived Product Images (DPI) of Total column Precipitable Water vapor (TPW) and atmospheric stability are being used by the National Weather Service forecast offices. Three layers of moisture derived from the GOES soundings are used operationally by regional forecast models over the land. Cloud properties at single field of view (FOV) resolution (approximately 10 km) are being generated and used. The effects of surface emissivity in profile retrievals from infrared multispectral radiances continue to be studied. Finally, GOES-12 performance was checked out during the fall of 2001 and added to the GOES Sounder family.

## 2. Performance of Operational GOES Soundings

Operational production of GOES-8/10 soundings continues every hour over North America and the nearby oceans. Comparison (of retrievals with 10 to 25 FOV clear out of 5x5 FOV) with raobs shows almost no bias and 3 mm scatter (see Figure 1). For the last several years, GOES retrievals at both CIMSS and NESDIS (Forecast Product Development Team and operations, designated as OPS) have been produced using a nonlinear physical retrieval algorithm (Ma et al. 1999). This algorithm uses GOES Sounder cloud-free radiances that have been averaged over N x N FOVs to adjust first guess vertical profiles of temperature and moisture. At CIMSS, the radiance averaging is done within a 3 X 3 matrix of FOVs, while the NESDIS operational retrievals are produced using a 5 X 5 FOV matrix. Since the nominal horizontal resolution of a GOES Sounder FOV is 10km, the nominal dimensions of the CIMSS and NESDIS retrievals are approximately 30 X 30 and 50 X 50 km, respectively. Table 1 shows the statistics from comparisons with respect to raobs for the past 3 years.

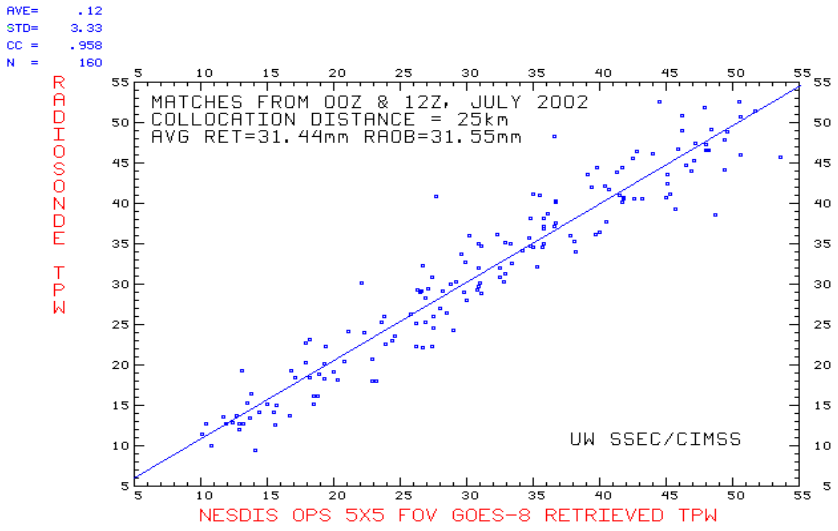


**Figure 1.** NESDIS operational GOES-8 Sounder TPW versus radiosondes for July 2002.

**Table 1.** Comparison of moisture (mm) for both the OPS and CIMSS retrievals for the periods April 1999 to March 2000, April 2000 to March 2001 and April 2001 to March 2002, showing the model first guess and the GOES-8/10 retrieval differences with respect to collocated radiosondes. Collocation distance is approximately 0.25 degrees latitude/longitude. Bias and standard deviation (SD) are indicated. Sigma levels are defined as the pressure divided by surface pressure.

| GOES-8 OPS/CIMSS | 1999-00 (Samples = 2322/6243) | | | | 2000-01 (Samples = 1944/6367) | | | |
|---|---|---|---|---|---|---|---|---|
| | Eta Guess | | Retrieval | | Eta Guess | | Retrieval | |
| | Bias | SD | Bias | SD | Bias | SD | Bias | SD |
| Total Water Vapor | -.2/-.3 | 3.2/3.4 | -.6/-.1 | 3.1/3.2 | -.4/-1.2 | 3.2/3.1 | -.5/-.9 | 3.1/3.0 |
| WV1 (Sfc to .9 σ) | -.5/-.5 | 1.4/1.5 | -.7/-.4 | 1.5/1.4 | -.7/-.9 | 1.5/1.4 | -.7/-.7 | 1.5/1.4 |
| WV2 (.9 to .7 σ) | -.1/-.1 | 1.9/1.9 | -.3/.0 | 1.8/1.9 | -.1/-.4 | 1.9/1.8 | -.1/-.3 | .9/1.8 |
| WV3 (.7 to .3 σ) | .3/.3 | 1.2/1.2 | .3/.3 | 1.0/1.1 | .2/.0 | 1.2/1.1 | .3/.1 | 1.0/1.0 |

| GOES-8 OPS/CIMSS | 2001-02 (Samples = 1598/7076) | | | |
|---|---|---|---|---|
| | AVN Guess | | Retrieval | |
| | Bias | SD | Bias | SD |
| Total Water Vapor | -.4/-1.2 | 3.7/2.9 | -.4/-1.2 | 3.1/2.7 |
| WV1 (Surface to .9 σ) | -.8/-.9 | 1.5/1.3 | -.7/-.8 | 1.5/1.3 |
| WV2 (.9 to .7 σ) | .0/-.4 | 2.2/1.7 | -.1/-.5 | 1.9/1.7 |
| WV3 (.7 to .3 σ). | 4/.0 | 1.5/1.1 | .4/.0 | 1.1/0.9 |

| GOES-10 OPS/CIMSS | 1999-00 (Samples = 667/2253) | | | | 2000-01 (Samples = 624/2282) | | | |
|---|---|---|---|---|---|---|---|---|
| | Eta Guess | | Retrieval | | Eta Guess | | Retrieval | |
| | Bias | SD | Bias | SD | Bias | SD | Bias | SD |
| Total Water Vapor | -.5/-.5 | 2.7/2.7 | -.4/-.2 | 2.6/2.4 | -.5/-1.0 | 2.8/2.6 | .0/-.7 | 2.7/2.3 |
| WV1 (Surface to .9 σ) | -.8/-.8 | 1.2/1.2 | -.8/-.8 | 1.1/1.2 | -.9/-1.1 | 1.1/1.2 | -.4/-.8 | 1.1/1.2 |
| WV2 (.9 to .7 σ) | .1/.2 | 1.5/1.5 | .1/.3 | 1.5/1.4 | .1/.0 | 1.5/1.4 | .1/.0 | 1.5/1.3 |
| WV3 (.7 to .3 σ) | .2/.2 | 1.1/.9 | .3/.3 | 1.0/.8 | .2/.1 | 1.2/1. | .3/.1 | .9/.7 |

| GOES-10 OPS/CIMSS | 2001-02 (Samples = 587/2379) | | | |
|---|---|---|---|---|
| | AVN Guess | | Retrieval | |
| | Bias | SD | Bias | SD |
| Total Water Vapor | -.5/-1.1 | 3.2/2.6 | .4/-1.0 | 3.0/2.3 |
| WV1 (Surface to .9 σ) | -1.1/-1.1 | 1.4/1.2 | -.5/-.8 | 1.4/1.2 |
| WV2 (.9 to .7 σ) | .2/-.1 | 1.7/1.3 | .3/-.2 | 1.7/1.3 |
| WV3 (.7 to .3 σ) | .4/.1 | 1.2/1.0 | .5/.0 | 1.0/.8 |

## 3. Single FOV Soundings

Single FOV (SFOV) retrievals are being investigated as the signal-to-noise ratio of the GOES sounders continues to improve with the May 2000 launch of GOES-11 and the July 2001 launch of GOES-12. SFOV retrievals can achieve coverage not possible with coarser resolution retrievals. A GOES-8 example is shown in Figure 2. Even with the relatively noisy performance on GOES-8, the single FOV DPI shows details not apparent in the 3x3 FOV DPI. Persistence from one time period to the next can confirm atmospheric signal from instrument noise.

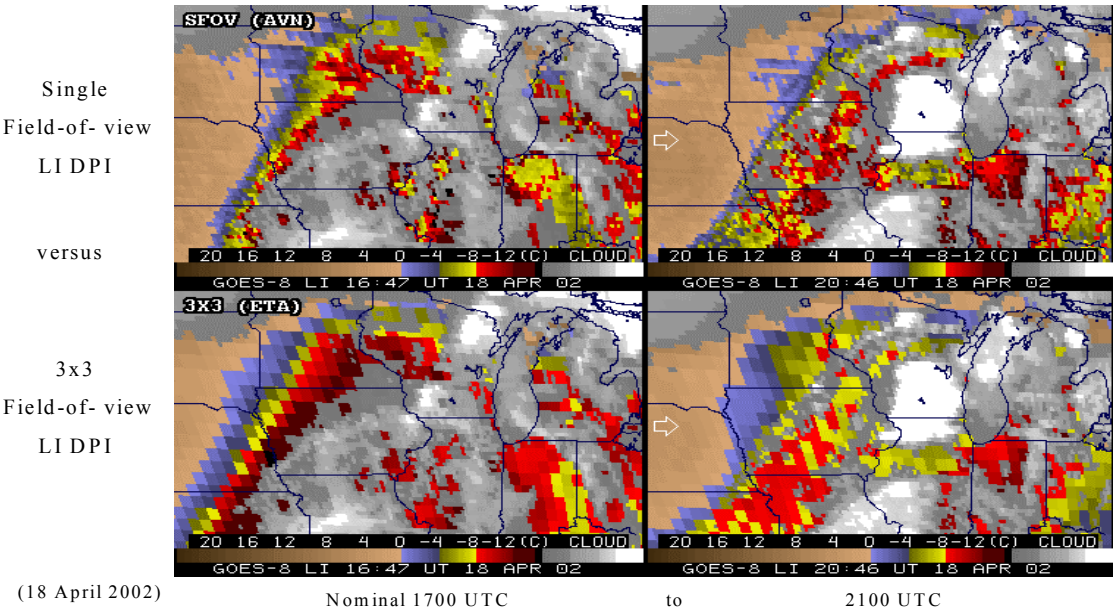


**Figure 2.** GOES-8 SFOV and 3x3 FOV DPI of Lifted Index for 17 and 21 UTC on 18 April 2002

## 4. GOES-12 Retrievals

During the GOES-12 check-out period, four primary displays of GOES-12 Sounder data were regularly shown on the CIMSS web page (http://cimss.ssec.wisc.edu/goes/g12_report/): they are (1) all spectral bands (ordered by decreasing wavelength) with one common color enhancement; (2) derived product imagery (DPI) of total precipitable water vapor combining TPW retrievals in clear locations with infrared window channel brightness temperature values ("cloud top temperatures") in the cloudy locations. (3) DPI of lifted index (LI), a stability parameter. (4) DPI of cloud top pressure (CTP) which combines cloud (pressure) heights with infrared window channel "surface temperatures" in the clear locations. Comparisons between GOES-12 and -8 show generally good agreement.

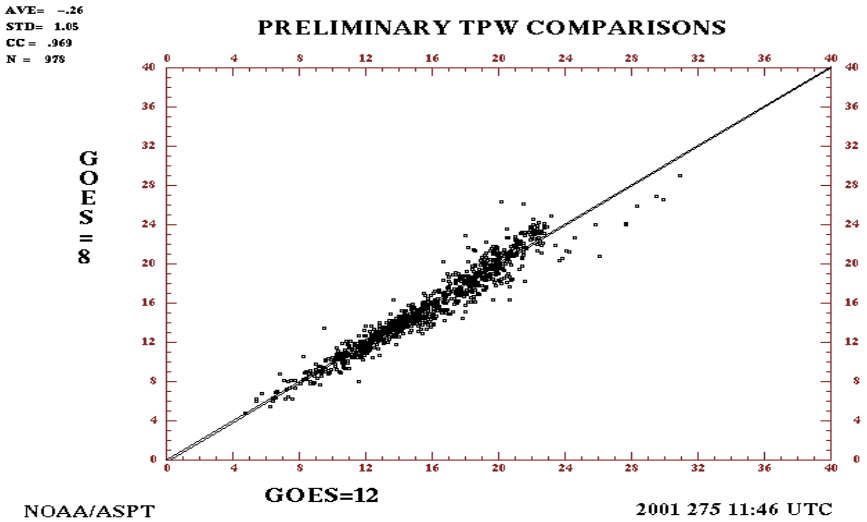


**Figure 3.** GOES-12 and –8 TPW retrieval RMS is 1 mm about a mean difference of 0.3 mm

## 5. IHOP and GOES-8/11 Retrievals

CIMSS generated GOES-8 single FOV retrievals and cloud products in preparation for the entire IHOP (International H2O Project) field experiment (11 Apr - 25 Jun 2002 - Oklahoma and Texas Panhandles).

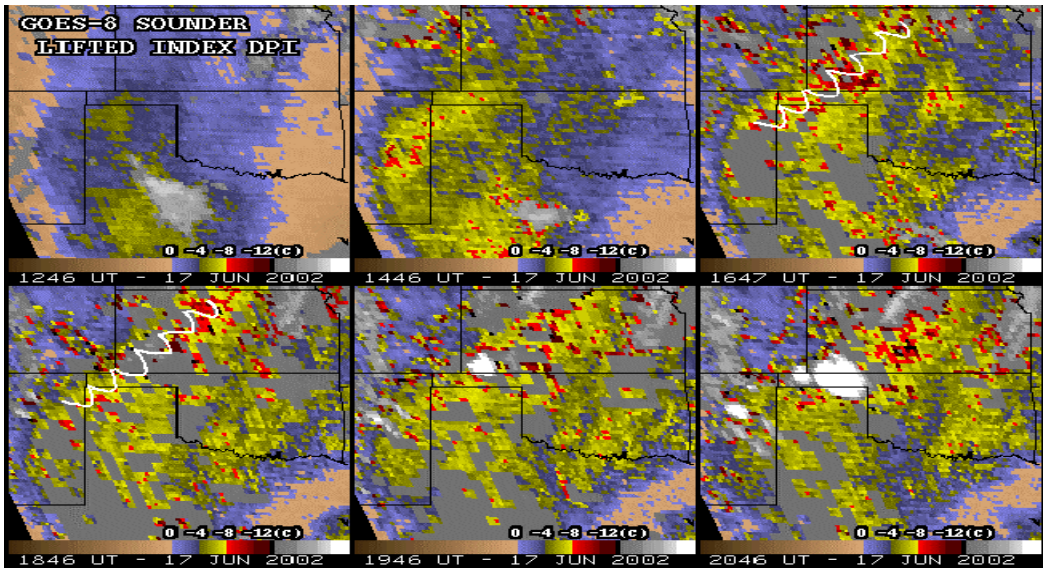


**Figure 4.** 13 to 23 UTC of GOES-8 Sounder single FOV lifted index product. The axis of instability (<-8) and the persistence in the sequence of two-hourly interval GOES LI DPI focus the attention for favorable convective conditions from central west Kansas through the Oklahoma and far northwest Texas Panhandles. Later severe weather reports included numerous hail reports (to 1.25") from the far northern Texas Panhandle into far southwest Kansas. Other hail also fell around the western central Kansas/Nebraska border region.

CIMSS also produced GOES-11 single FOV retrievals (and cloud products) for most of the portion of IHOP that GOES-11 was activated. NESDIS took GOES-11 out of storage mode on 29 May 2002 and returned it to storage mode on 21 June 2002.

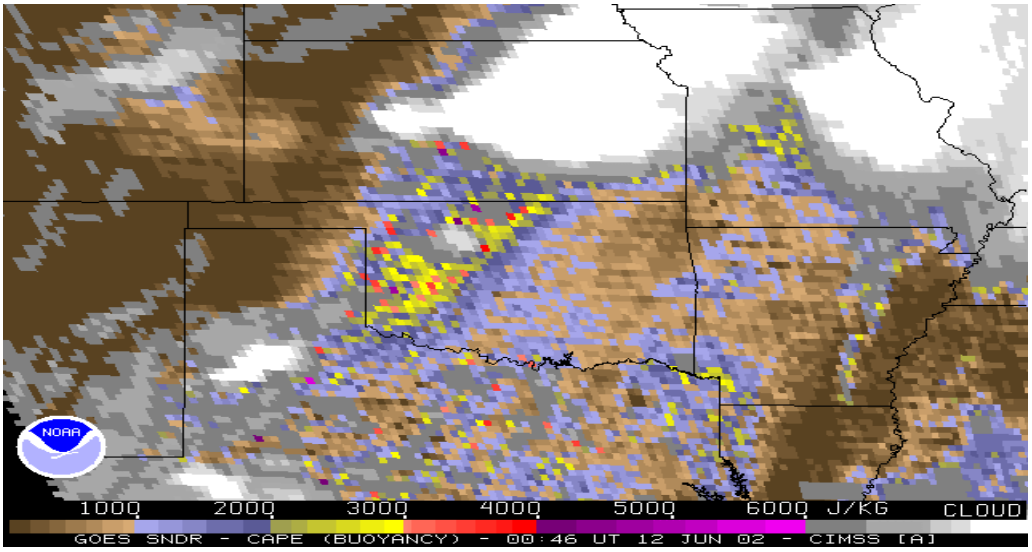


**Figure 5.** Example GOES-11 SFOV image of CAPE.

## 6. Imager Clear-Sky Brightness Temperature

A new product based on 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.

NESDIS / ORA together with CIMSS developed software to select cloud-free fields-of-view (FOVs), to average these data to 50 km areas, and to stage the information to BUFR formatted files. This product provides clear sky information for the five spectral bands from both the GOES-8 (East) and –10 (West) Imagers. Since early November 2001, CIMSS has produced hourly, hemispheric coverage of these data. EMC and ECMWF have successfully accessed and decoded the CSBT data and bring it into their databases routinely. ECMWF performed a preliminary evaluation of the GOES Imager CSBT and found the water vapor channel (band 3, 6.7 um) to be of good quality. ECMWF is performing assimilation experiments and plans to use these data operationally in the near future; ECMWF is currently using clear-sky radiances from the METEOSAT. They report that when assimilating the GOES-E/W CSBT, corrections to the upper tropospheric humidity field in areas of known model deficiencies are observed. A positive influence is seen particularly in the agreement of the model with other WV radiances from the High-resolution Infrared Sounder, HIRS-12, and the Advanced Microwave Sounding Unit, AMSUB-3. EMC has similar plans; they noted that the cloud-detection required a more stringent technique for the surface-viewing bands which was completed during the summer of 2002.

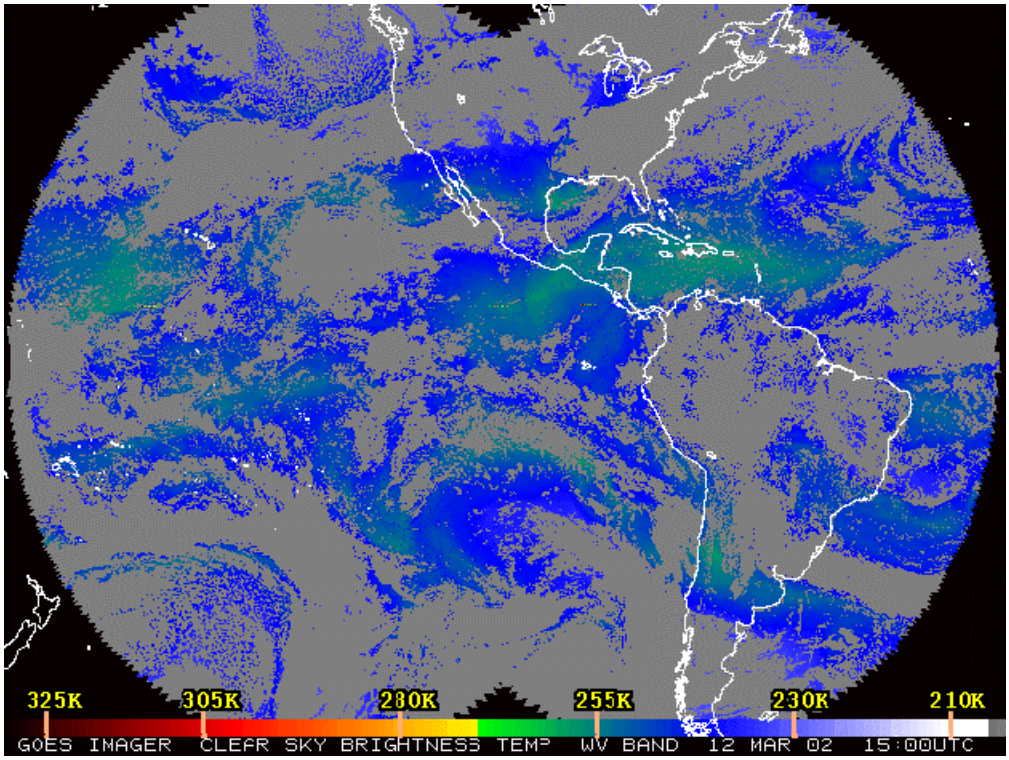


**Figure 5.** Combined GOES-8 & -10 Imager Water Vapor Band (6.7 μm) CSBT Image.

## 7. Acounting for Surface Emissivity

To retrieve vertical profiles of temperature and moisture from infrared spectral measurements, surface emissivity must be accounted for in the physical solution of the inverse problem (see Figure 6). A radiative model that includes the emission and reflection on the lower atmospheric boundary has been developed. An algorithm has been tested for solution of vertical temperature-humidity profile as well as estimation of an effective surface emissivity and temperature within the

sounding area. Results using spectral measurements from the GOES-8 Sounder indicate that accounting for the surface emissivity in the solution of the inverse problem impacts the meteorological profiles positively (see Figure 7); the emissivity estimates are stable from one time period to the next (see Figure 8).

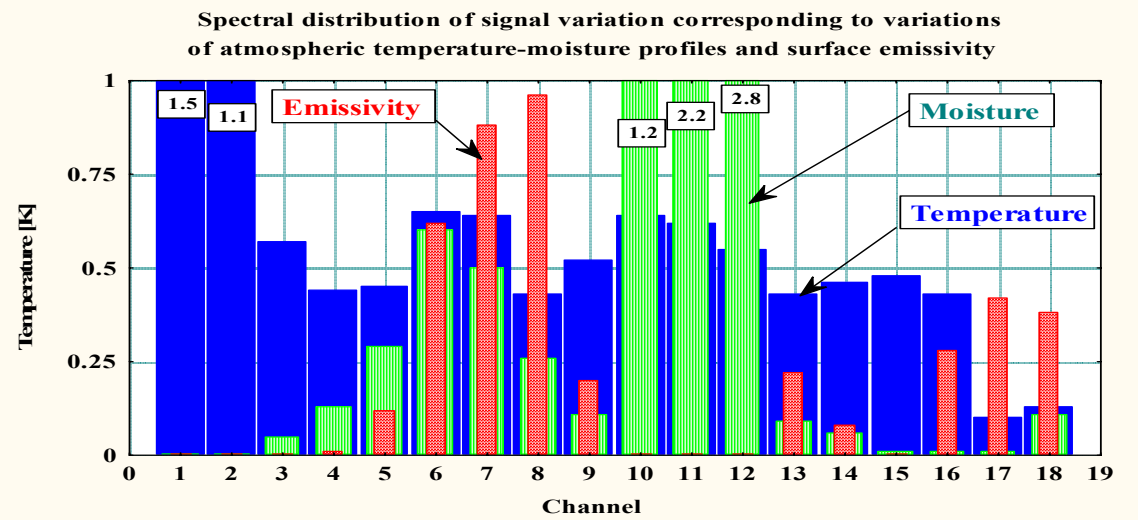


**Figure 6.** Deviation of the calculated brightness temperatures in each spectral channel corresponding to changes in the atmospheric temperature or moisture equal to the Raob minus ETA model first guess standard deviations or surface emissivity increasing by 0.02 (from 0.96 to 0.98). Values exceeding 1.0 K in the spectral channels are indicated explicitly

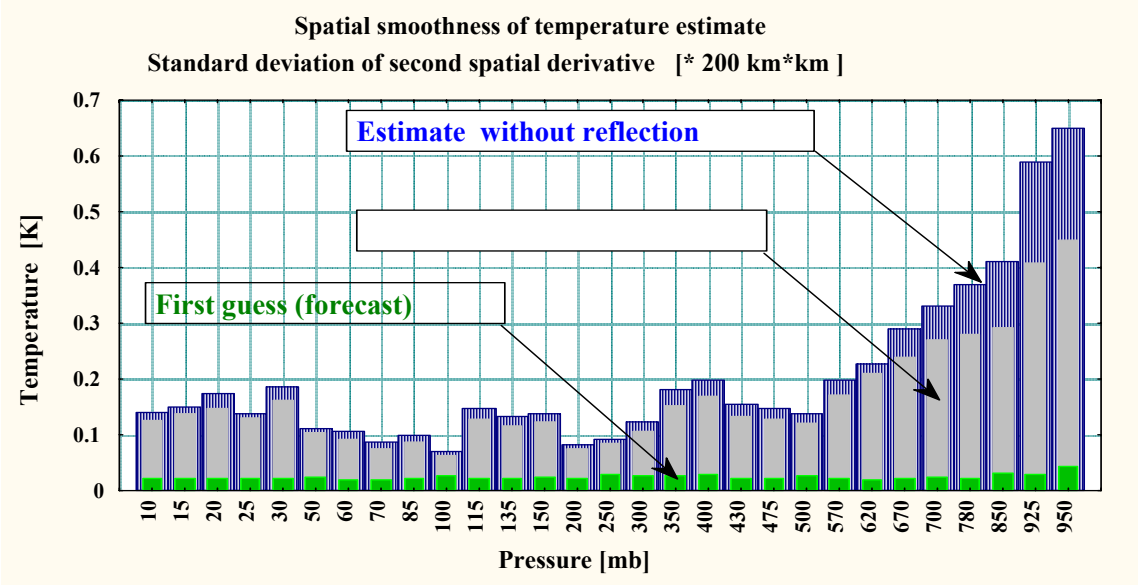


**Figure 7.** Standard deviation of the spatial differential $\frac{\partial^2 \hat{T}}{\partial x^2}(\delta x)^2 + \frac{\partial^2 \hat{T}}{\partial y^2}(\delta y)^2$ of the temperature profile and the average absolute temperature difference of RAOB measurements and satellite estimates

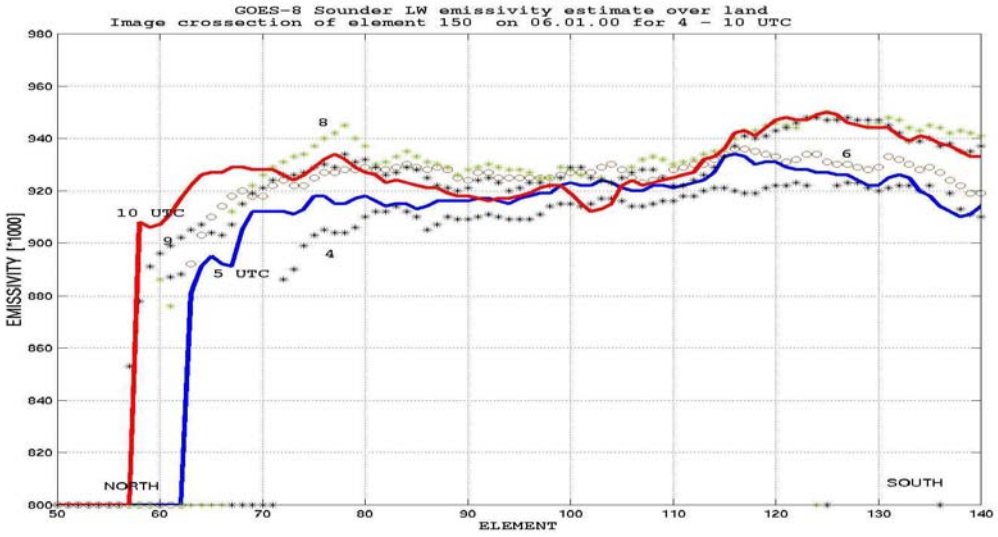


**Figure 8.** Changes in LW emissivity estimate on 1 June 2000 from 4 to 10 UTC LW emissivity cross section north to south shows 6 hour changes up to 4%

**Recent References**

Bayler, G. M, S. Wetzel Seemann, J. Li, and T. J. Schmit, 2001: Is the resolution of GOES sounder data sufficient to support single field of view retrievals and derived products? Preprints, *11th Conf. on Satellite Meteorology and Oceanography*, Madison, WI, Amer. Meteor. Soc., 351-354.

Daniels, J. M. and T. J. Schmit, 2001: GOES-11 Imager and Sounder Radiance and Product Validations. NOAA Tech. Memo., NESDIS 103, U.S. Department of Commerce, Washington, DC.

Ferraro, R. and J. Daniels, 2001: A comparison of GOES and AMSU based total precipitable water retrievals. Preprints, *Fifth Symposium on Integrated Observing Systems*, Albuquerque, NM, Amer. Meteor. Soc., 130-131.

Nelson, J. P. III, T. J. Schmit, and W. P. Menzel, 2001: An evaluation of several years of CIMSS and NESDIS GOES sounder data. Preprints, *11th Conf. on Satellite Meteorology and Oceanography*, Madison, WI, Amer. Meteor. Soc., 359-362.

Plokhenko, Y., and W. P. Menzel, 2000: Mathematical aspects for meteorological processing of infrared spectral measurements from the GOES sounder: I. Constructing the measurement estimate using spatial smoothing. *J. Appl. Meteor.*, **40**, 556-567.

Plokhenko, Y., W. P. Menzel, G. Bayler, and T. J. Schmit, 2002: Mathematical aspects in meteorological processing of infrared spectral measurements from the GOES sounder. II. Analysis of spatial and temporal continuity of spectral measurements from the GOES-8 Sounder. Accepted by *J. Appl. Meteor.*

Schmit, T. J., E. M. Prins, A. J. Schreiner, and J. J. Gurka, 2001: Introducing the GOES-M imager. Accepted by *Nat. Wea. Dig.*, **25** (3,4).