CGMS XXXII NOAA-WP-27
Agenda Item: II/3
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2003 / 2004 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. Improvements under study are also summarized

Action Requested: None

2003 / 2004 REPORT ON NOAA/NESDIS GOES SOUNDINGS

Timothy J. Schmit [1], W. Paul Menzel [1], Jaime Daniels [1], Gary Ellrod [1],
James P. Nelson III [2], Jim Jung [2], Tony Schreiner [2]

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

1. Introduction

The NOAA/NESDIS operational Geostationary Operational Environmental Satellite (GOES) East (GOES-12) and West (GOES-10) soundings continue to be produced nearly every hour at approximately 50 km resolution (5X5 Fields of View (FOV)) in clear skies from radiance data supplied by the GOES Sounder. Additionally, GOES-9 (at 155 E) products are being generated in an experimental mode. Research retrievals are routinely generated at single FOV resolution (approximately 10 km); operational retrievals are evolving to single FOV. Derived Product Images (DPI) of Total column Precipitable Water vapor (TPW) and atmospheric stability (Lifted Index, LI) are being used by the National Weather Service forecast offices. The 5x5 FOV derived products are also available on the Advanced Weather Interactive Processing System (AWIPS); some of the GOES sounder bands will also soon be available in the AWIPS. Three layers of moisture derived from the GOES soundings are used operationally by regional forecast models over land. Cloud Top Pressure and Effective Cloud Amount at single field of view (FOV) resolution (approximately 10 km) are being generated and used in several numerical weather prediction models. Recent research has shown that the GOES sounder channels can detect some upper-level SO_2 events.

2. Performance of GOES Soundings

Operational production of GOES-East and -West soundings continues nearly every hour over North America and adjacent oceans. For the last several years, GOES retrievals at NESDIS operations (designated as OPS), CIMSS (Cooperative Institute for Meteorological Satellite Studies), and FPDT (NESDIS Forecast Products Development Team) have been produced using a nonlinear physical retrieval algorithm. 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 NOAA NESDIS, the operational retrievals are produced using a 5 X 5 FOV matrix, while at CIMSS the radiance averaging is done within a 3 x 3 matrix of FOVs. The FPDT retrievals are produced at the nominal single FOV resolution. Since the nominal horizontal resolution of a GOES Sounder FOV is 10km, the nominal dimensions of the NOAA NESDIS and CIMSS retrievals are approximately 50 X 50 and 30 X 30 km, respectively.

Statistics from operational NESDIS 5x5 FOV retrievals and collocated radiosondes are shown in Table 1. For reference, statistics from 3 x 3 FOV retrievals produced at CIMSS are also shown. The statistics are valid for the period 1 June 2003 through 31 January 2004. In general, the standard deviation (SD) was reduced when comparing retrievals and radiosondes versus retrieval guesses and radiosondes. Furthermore, the correlation coefficient (CC) increased from the guess/radiosonde to the retrieval/radiosonde comparisons. This means the retrieved moisture information tended to more closely mimic the radiosonde data than did the guess as one compared successive retrieval/radiosonde pairs.

Table 1. Moisture (mm) retrieval differences from 1 June 2003 (2003151) through 31 January 2004 (2004031) between the AVN (GFS) model first guess and various GOES Sounder retrievals with respect to collocated (within 0.25 degrees latitude/longitude) radiosonde observations. Bias and standard deviation (SD) are indicated. Sigma levels are defined as the pressure divided by surface pressure. Minimum clear retrieval Fields of View (FOV) required are 4 (out of 9 possible) for each 3x3 FOV match, 10 (out of 25 possible) for each 5x5 FOV match. GS = retrieval guess, RT = retrieval, RB = radiosonde, SB2S2 = SQRT(BIAS**2 + SD**2), WV = Total Precipitable Water vapor, WV1 = 1.0 sigma -> 0.9 sigma (approximately 1000hPa -> 900hPa), WV2 = 0.9 sigma -> 0.7 sigma (900 -> 700), and WV3 = 0.7 sigma -> 0.3 sigma (700 -> 300). Red numbers denote GOES-12 and –10 NESDIS Operational 5x5 FOV retrievals. Blue numbers denote GOES-12 and -10 CIMSS 3x3 FOV retrievals.

	BIAS(mm)	SD(mm)	SB2S2	AVGX(mm)	AVGY(mm)	CC	N		
TPW,G12	0.48	3.68	3.71	23.25	22.76	0.960	760	GS wrt RB	,OPS 5x5
	-0.75	3.22	3.31	22.01	22.76	0.969	760	RT wrt RB	,OPS 5x5
G12	0.34	3.61	3.63	21.05	20.71	0.962	4298	GS wrt RB	,CMS 3x3
	-0.43	3.13	3.16	20.29	20.71	0.970	4298	RT wrt RB	,CMS 3x3
TPW,G10	-0.84	3.65	3.75	15.30	16.14	0.920	324	GS wrt RB	,OPS 5x5
	-1.04	3.46	3.61	15.09	16.14	0.932	324	RT wrt RB	,OPS 5x5
G10	-0.32	3.44	3.46	13.43	13.75	0.915	1669	GS wrt RB	,CMS 3x3
	0.23	2.81	2.82	13.98	13.75	0.946	1669	RT wrt RB	,CMS 3x3
WV1,G12	-0.69	1.46	1.61	8.14	8.83	0.952	760	GS wrt RB	,OPS 5x5
	-0.64	1.50	1.63	8.19	8.83	0.950	760	RT wrt RB	,OPS 5x5
G12	-0.70	1.45	1.61	7.40	8.10	0.955	4298	GS wrt RB	,CMS 3x3
	-0.69	1.41	1.57	7.42	8.10	0.958	4298	RT wrt RB	,CMS 3x3
WV1,G10	-1.58	1.70	2.32	4.36	5.95	0.831	324	GS wrt RB	,OPS 5x5
	-0.74	1.53	1.70	5.21	5.95	0.865	324	RT wrt RB	,OPS 5x5
G10	-1.08	1.42	1.78	3.72	4.80	0.862	1669	GS wrt RB	,CMS 3x3
	-0.63	1.31	1.45	4.17	4.80	0.885	1669	RT wrt RB	,CMS 3x3
WV2,G12	0.50	2.10	2.16	10.54	10.03	0.939	760	GS wrt RB	,OPS 5x5
	0.21	1.97	1.98	10.24	10.03	0.950	760	RT wrt RB	,OPS 5x5
G12	0.46	2.10	2.15	9.51	9.05	0.939	4298	GS wrt RB	,CMS 3x3
	0.34	1.93	1.96	9.39	9.05	0.948	4298	RT wrt RB	,CMS 3x3
WV2,G10	0.29	2.10	2.12	7.26	6.97	0.889	324	GS wrt RB	,OPS 5x5
	0.13	2.17	2.17	7.09	6.97	0.901	324	RT wrt RB	,OPS 5x5
G10	0.28	1.89	1.91	6.37	6.09	0.887	1669	GS wrt RB	,CMS 3x3
	0.49	1.73	1.79	6.57	6.09	0.913	1669	RT wrt RB	,CMS 3x3
WV3,G12	0.64	1.45	1.59	4.48	3.84	0.891	760	GS wrt RB	,OPS 5x5
	-0.33	1.11	1.16	3.50	3.84	0.930	760	RT wrt RB	,OPS 5x5
G12	0.55	1.38	1.49	4.06	3.51	0.897	4298	GS wrt RB	,CMS 3x3
	-0.08	1.02	1.03	3.43	3.51	0.935	4298	RT wrt RB	,CMS 3x3
WV3,G10	0.44	1.26	1.33	3.62	3.18	0.897	324	GS wrt RB	,OPS 5x5
	-0.44	1.09	1.17	2.74	3.18	0.910	324	RT wrt RB	,OPS 5x5
G10	0.46	1.18	1.27	3.28	2.82	0.882	1669	GS wrt RB	,CMS 3x3
	0.37	0.95	1.02	3.19	2.82	0.925	1669	RT wrt RB	,CMS 3x3

GOES-12 total column water vapor is also being validated at the DOE ARM CART site near Lamont, Oklahoma, USA. Comparisons between the GOES-12 Sounder moisture retrievals produced and a Microwave Radiometer (MWR) show good agreement (see Figure 1).

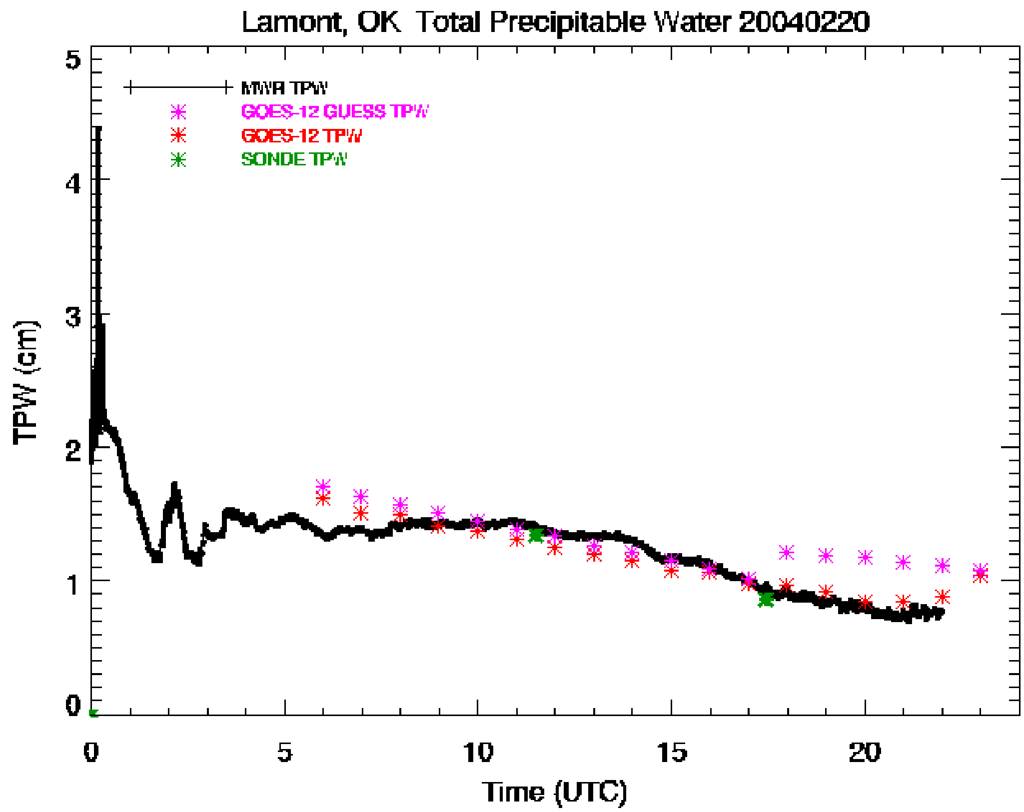

Figure 1. GOES-12 sounder TPW validations with a Microwave Radiometer (MWR) at the Department of Energy – Atmospheric Radiation Program (DOE ARM) Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site. Microwave radiometer (solid line), numerical model forecast (diamonds), rawinsonde measurement (asterisks) and GOES-12 physical retrieval (plus symbols) of total precipitable water vapor value are compared near Lamont, Oklahoma on 20 February 2004 are plotted.

In a collaborative effort, CIMSS and National Center for Environmental Prediction (NCEP) personnel assimilated GOES-12 Sounder products in the Eta Data Assimilation System (EDAS). CIMSS helped to verify data distribution, timing, quality and quantity of GOES-12 Sounder 3-layer Precipitable Water and the single field of view cloud product to ensure a smooth transition from GOES-8 to GOES-12. The GOES-12 Sounder 3-layer Precipitable Water product is now in the operational EDAS and the Rapid Update Cycle (RUC).

3. Single FOV Soundings

Single FOV (SFOV) retrievals are being generated by both FPDT and CIMSS; 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 achieve coverage not possible with coarser resolution retrievals. A new “merged” retrieval system from FPDT produces not only SFOV retrievals, but also the SFOV cloud product; these will be implemented operationally in 2004. Sample DPIs of skin temperature and TPW are shown in Figures 2 and 3.

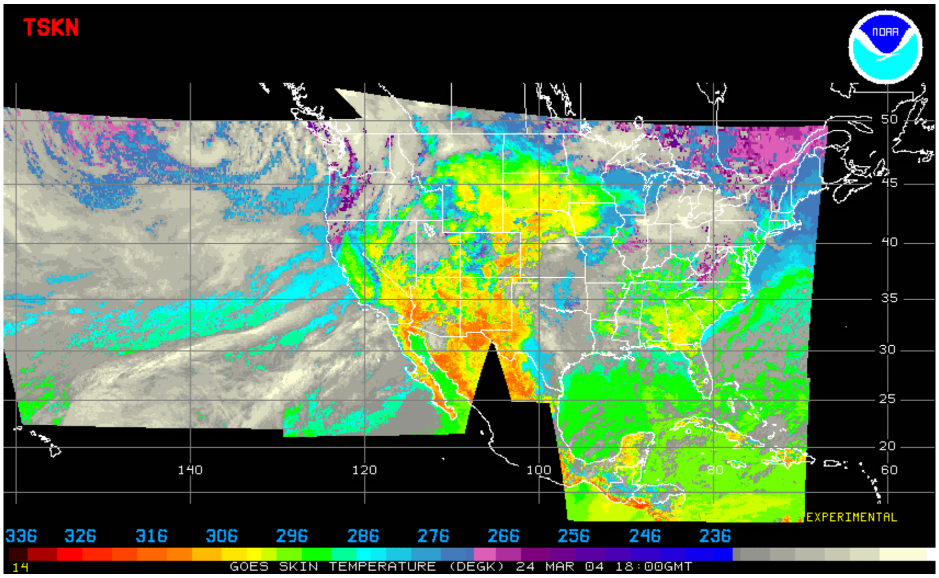

Figure 2. SFOV GOES Sounder skin temperature DPI produced by FPDT on 24 March 2004 at approximately 18 UTC.

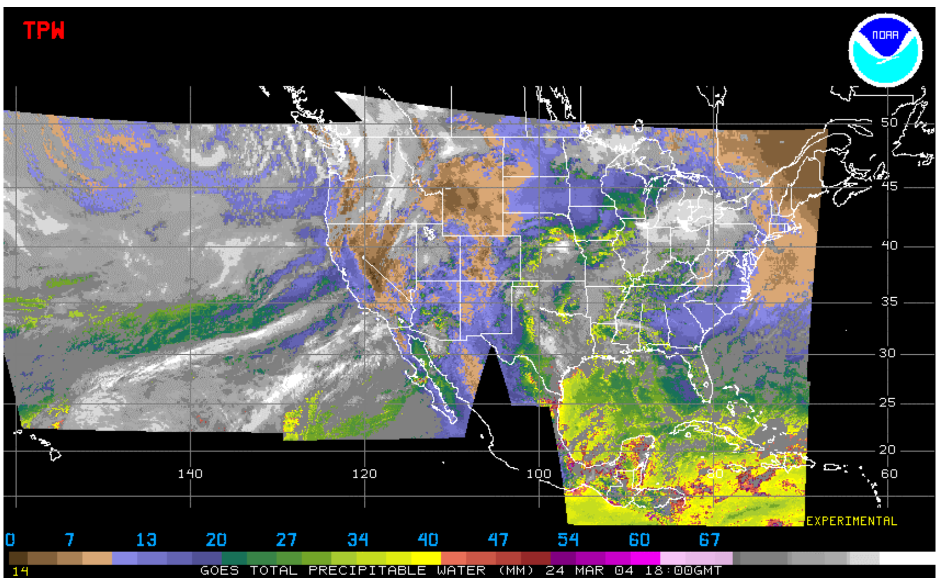

Figure 3. SFOV GOES Sounder total Precipitable water DPI produced by FPDT on 24 March 2004 at approximately 18 UTC.

4. GOES-9 Retrievals

With GOES-9 over the western Pacific (155 E) since May 2003, additional coverage in Sounder data and products has been available. These experimental products include TPW and cloud-product information. Displays of GOES-9 real time radiance data (Figure 4) and products can be found at http://cimss.ssec.wisc.edu/goes/realtime/grtmain.html#gsall).

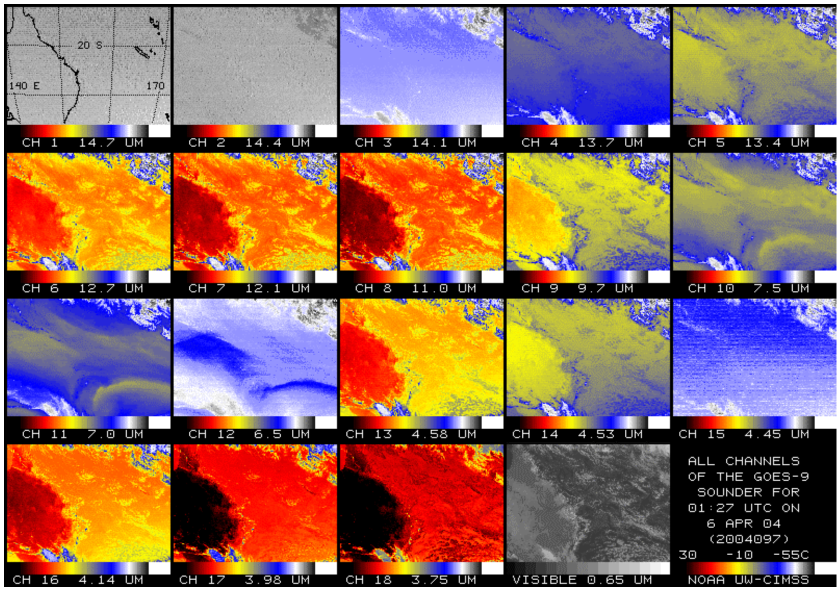

Figure 4. GOES-9 Sounder Radiance Data for approximately 130 UTC on 6 April 2004 the 18 infrared bands are shown. This is the 6-hourly scan sector over the eastern part of Australia.

5. Imager Clear-Sky Brightness Temperature

A 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 in global weather prediction models (Figure 5). 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. These hourly clear sky brightness temperature (CSBT) fields for the water vapor spectral band from GOES-9 (Far East), GOES-12 (East), and GOES–10 (West) Imagers are being used operationally by ECMWF; EMC is looking at GOES-10/12 data.

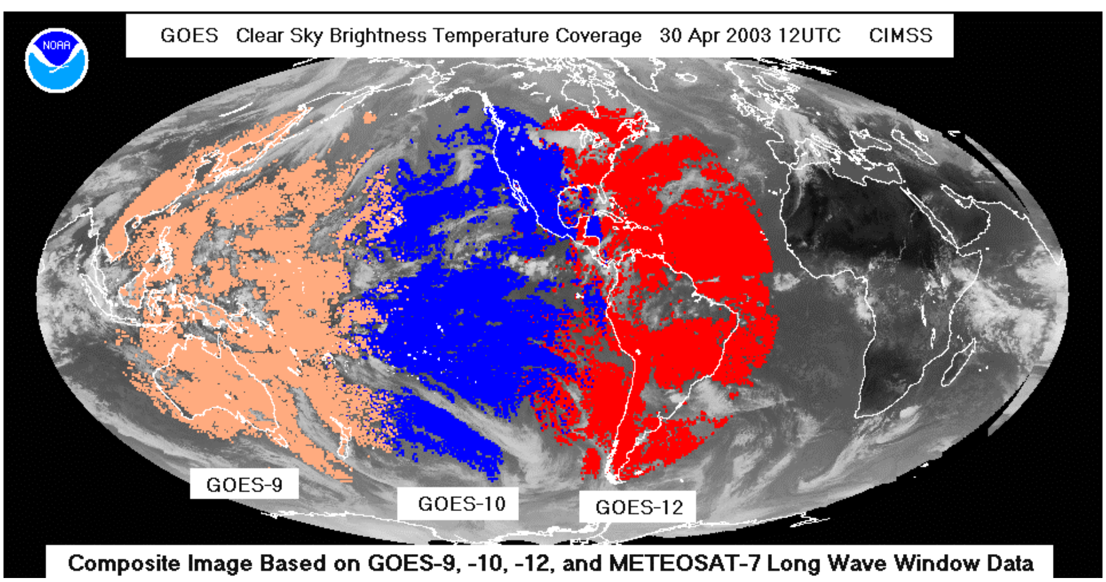

Figure 5. Combined GOES-9, -10 & -12 Imager Infrared window Band CSBT Image.

6. GOES Imager Cloud-top information

When GOES-12 replaced GOES-8, a new cloud-top information product was possible from the GOES-12 imager measurements in 13.3 and 11 microns (Figure 6). This product is running experimentally each hour at CIMSS.

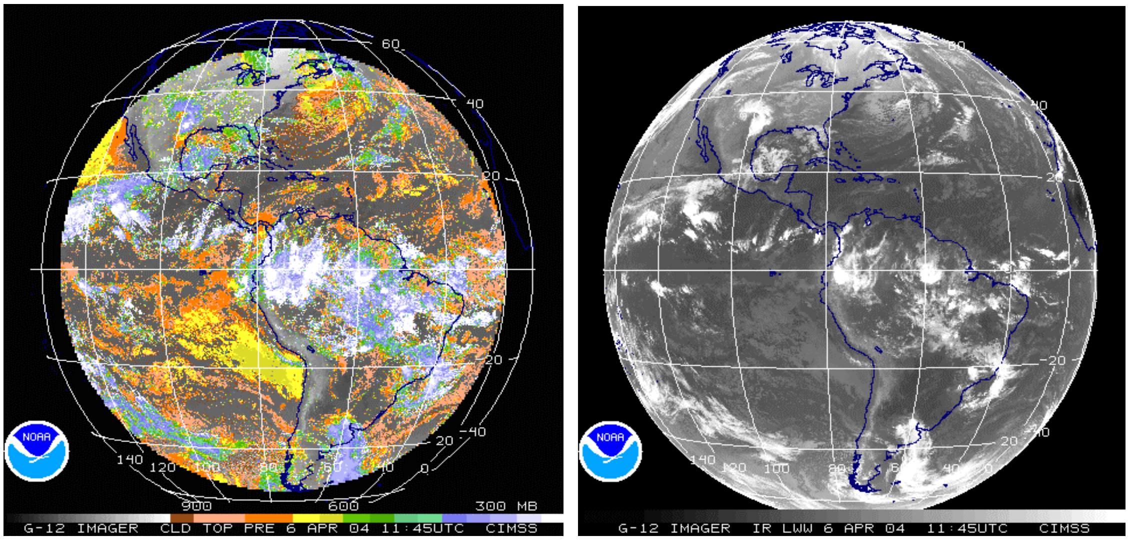

Figure 6. GOES-12 Imager, Cloud-Top Pressure and IRW from 1145 UTC on 6 April 2004.

7. GOES Sounder detection of SO_2

Sulfur Dioxide (SO_2) is often associated with volcanic eruptions. Geostationary satellites offer a rapid refresh rate and constant viewing angle and consequently the potential to provide continuous coverage of some SO_2 plumes, although there can be large satellite zenith angle limitations. This is important for aviation interests, as SO_2 may be helpful in confirming the presence of volcanic ash.

The current GOES Imager covers neither the 7.3 μm nor the 8.5 μm spectral regions that are associated with SO_2 absorption (hence detection). The GOES Sounder has a band at 7.46 μm (Band 10) that covers part of the 7.3 μm SO_2 band and should be sensitive to upper-level SO_2. Figure 7 shows detection of an eruption (13-15 July 2003) of the Soufriere Hills Volcano, Montserrat, located in the eastern Caribbean, using a difference of the SO2 sensitive band 10 with an SO2 insensitive band 5 (13.3 μm). Over the course of three days, four eruptions took place and thus offered an opportunity to evaluate the GOES Sounder monitoring of the upper level SO_2 coverage.

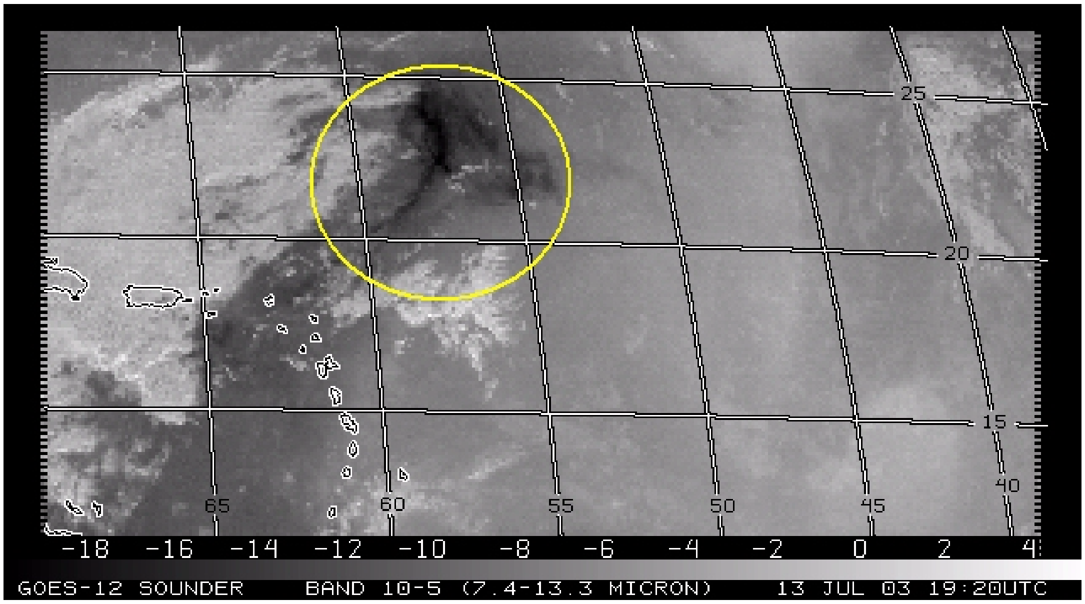

Figure 7. GOES-12 Sounder Difference Image (bands 5 and 10) 19:20 UTC on 13 July 2003. The plume is within the circle.

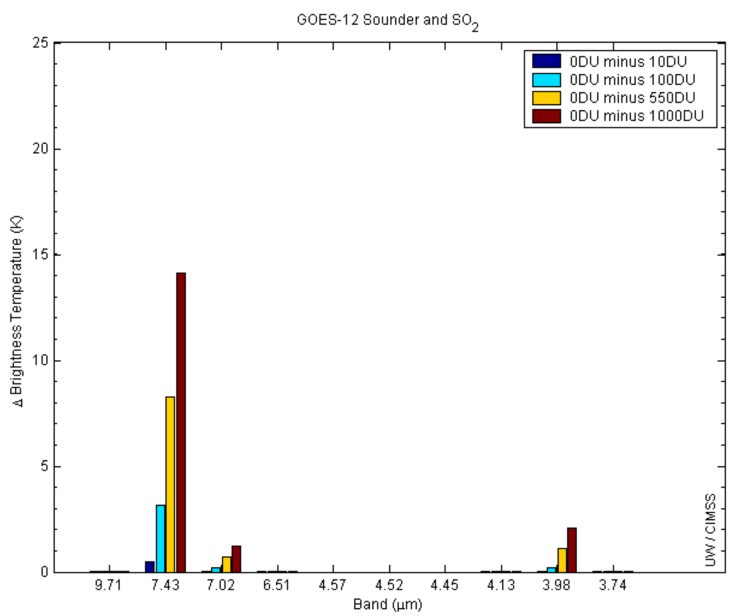

Figure 8. Forward calculations showing the brightness temperature impact of SO_2 on several bands on the GOES Sounder. The bar graph is the brightness temperature differences between a simulated atmosphere with no SO_2 and atmospheres of varying amounts of SO_2.

8. GOES Sounder Clouds and NWP

As of 8 July 2003, hourly cloud-top information from the GOES Sounder data is being assimilated into the operational National Centers for Environmental Prediction (NCEP) Eta Data Assimilation System (EDAS). The regional Eta model joins the Rapid Update Cycle (RUC) model as an operational model assimilating GOES Sounder cloud information to help improve the initial moisture and cloud fields. The regional CIMSS Regional Assimilation System (CRAS) model pioneered the use of GOES Sounder cloud product information in a numerical model.

More and more sounder data are being used in forecast models to better define the moisture and cloud fields. Figure 9 shows a comparison of (bottom) GOES Imager (observed) imagery and (top) coincident CRAS (CIMSS Regional Assimilation System) "forecast" imagery, for valid periods (left) 12z and (right) 18z on 08 Apr 2004. All images are for the 11 um IR window. The CRAS model assimilates GOES Sounder cloud top pressure (CTP) and three layers of precipitable water (PW). More comparisons are available at http://cimss.ssec.wisc.edu/goes/realtime/cf/.

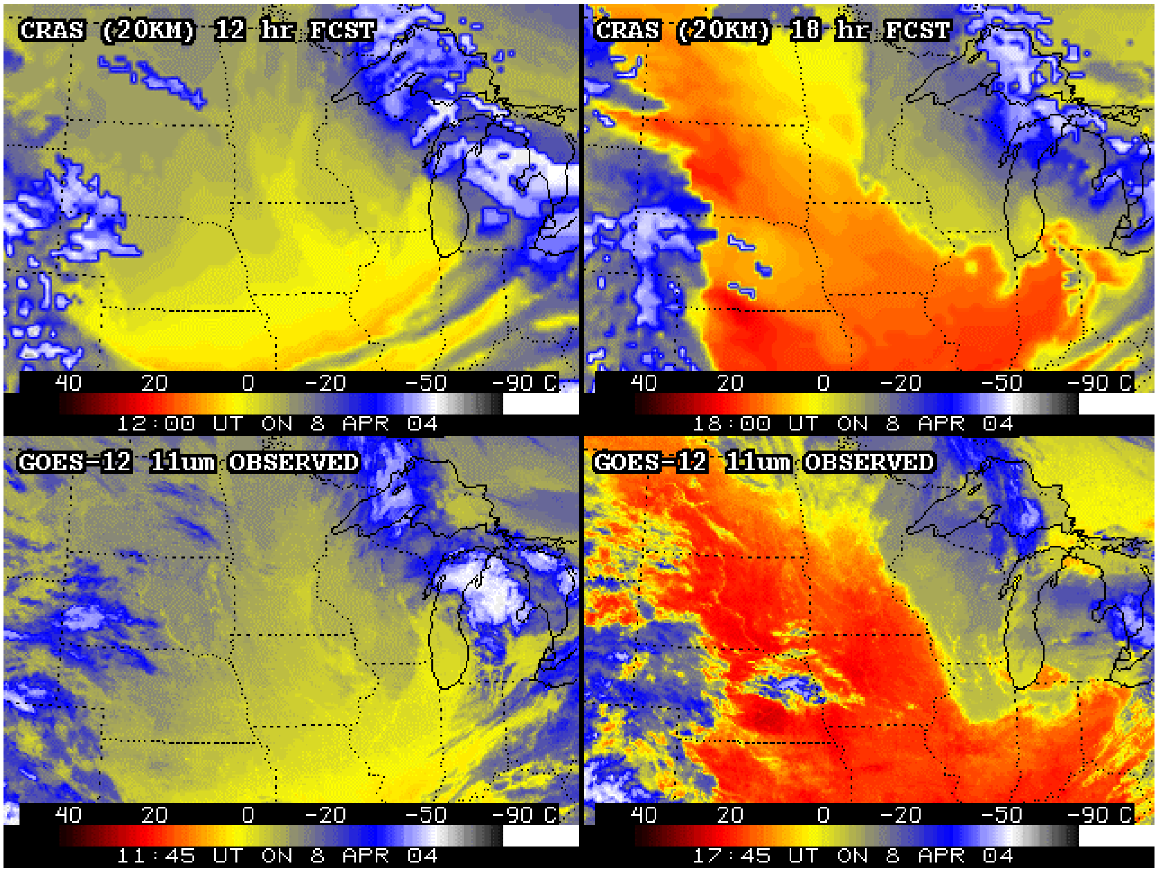

Figure 9. Forward calculations from a regional model compared against those from the GOES Imager. Note the fair correlation for cloud cover for both the 12 and 18 hr forecast times.

Acknowledgment

Fred Prata (CSIRO Atmospheric Research Australia) and Hal Woolf (CIMSS) are thanked for their collaborations on the SO_2 ash plumes. Robert M. Aune (NESDIS/ASPT) and Gary S. Wade (NESDIS/ASPT) provided figure 9.

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