

APPLICATION OF LIMB ADJUSTMENT TECHNIQUES FOR POLAR ORBITING SOUNDING DATA

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1.0 INTRODUCTION

The National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Environmental Services (NOAA/NESDIS) produces operational sounding products from the TIROS Operational Vertical Sounder (TOVS) onboard the polar orbiting satellites NOAA-11, NOAA-14 and, most recently, NOAA-15. With the launch of NOAA-15, the Advanced Microwave Sounding Unit-A (AMSU-A) and the Advanced Microwave Sounding Unit-B (AMSU-B) replaced the Microwave Sounding Unit (MSU) and the Stratospheric Sounding Unit (SSU) instruments of the earlier satellites. The High resolution Infrared Radiation Sounder, Model 2 (HIRS/2) instrument was also replaced with HIRS/3. Hence, the instrument ensemble is collectively known as the Advanced TOVS (ATOVS).

The operational sounding products are created via the Soundings Products Generation System (SPGS). This is a collection of software that processes all of the instrument data and produces the retrieval, climate and surface products. Additional ATOVS details can be found in Reale et. al. (1999). A property of the instruments is that they are cross-track scanners. Hence, radiation detected at the nadir field of view is different than radiation detected at each of the scan angles over homogenous surfaces. To compensate for these differences, the SPGS requires that the input data be adjusted to the nadir field of view. This allows a simpler processing than would be necessary if the data was not adjusted. Furthermore, quality checks of the data are possible and any intermediate products can be easily assessed.

The SPGS uses coefficients, derived from regression, to adjust data at each scan angle. These coefficients are derived from the algorithm described in Wark (1993). There are three major components to this algorithm. In the first part, five days of data is collected and converted into latitudinal temperature means for each beam position, channel and surface type. Secondly, the data is then passed through a quadratic function of the zenith angle:

$$T(z) = d_0 + d_1 * [\sec(z)-1] + d_2 * [\sec(z)-1] * [\sec(z)-1] \quad (1)$$

where z is the zenith angle, d_0, d_1 , and d_2 are derived coefficients and T is temperature. This function evens out the wild fluctuations, due to clouds, that were apparent in the coefficients across the swath. Lastly, the final coefficients are computed using a predetermined set of predictor channels by linear regression.

Several modifications were made to implement the limb adjustments for ATOVS. First, the limb adjustment coefficient generation software was converted from QuickBasic to C and transported from a PC platform to a UNIX workstation. Also, the data collection was automated by having the SPGS extract a subsample of the input data and transfer the subsample to the workstation. Limb adjusted data was placed onto rotating orbital data files at the instrument field of view for evaluation purposes.

2.0 TOVS EVALUATION

Before the launch of ATOVS, evaluation of the coefficients was performed via image analysis. Areas of relatively flat temperature fields were chosen and temperature comparisons between the nadir position and the limb were performed. The inadequacy of this method was realized when scan bias plots of the NOAA-11 and NOAA-14 infrared and microwave channels were received from the European Centre for Medium-range Weather Forecasting (ECMWF) (Saunders, private communication). Figure 1 shows the infrared channel scan biases for NOAA-14 and NOAA-11. The top two plots show the scan biases for the May, 1998 time period. Large scan biases are apparent in the infrared channels. New sets of coefficients were developed for the infrared channels of NOAA-14 and the microwave channels for both satellites (not shown). These were implemented in early July. Another set of scan biases were received from ECMWF for the August, 1998 time period and the results of the infrared channels for NOAA-14 and NOAA-11 are shown in the bottom four plots in Fig. 1. Much smaller scan biases were observed for most of the infrared channels except for HIRS channels 13, 14, and 15, with negligible impact on the MSU (not shown). In addition, the bottom four plots in Figure 1 also show that NOAA-14 biases have become comparable to NOAA-11. All things being equal, the bias similarity between satellites is an important result for the sounding products. Further image analysis of the data after using the new coefficients did not show the amount of bias that was observed in the plots. This suggests that sampling characteristics of the data may be contributing to the apparent bias. Hence, for ATOVS, similar plots were developed to compliment the image analysis. The plotted residuals were computed by subtracting the mean temperature at the nadir position from the mean temperature at each beam position.

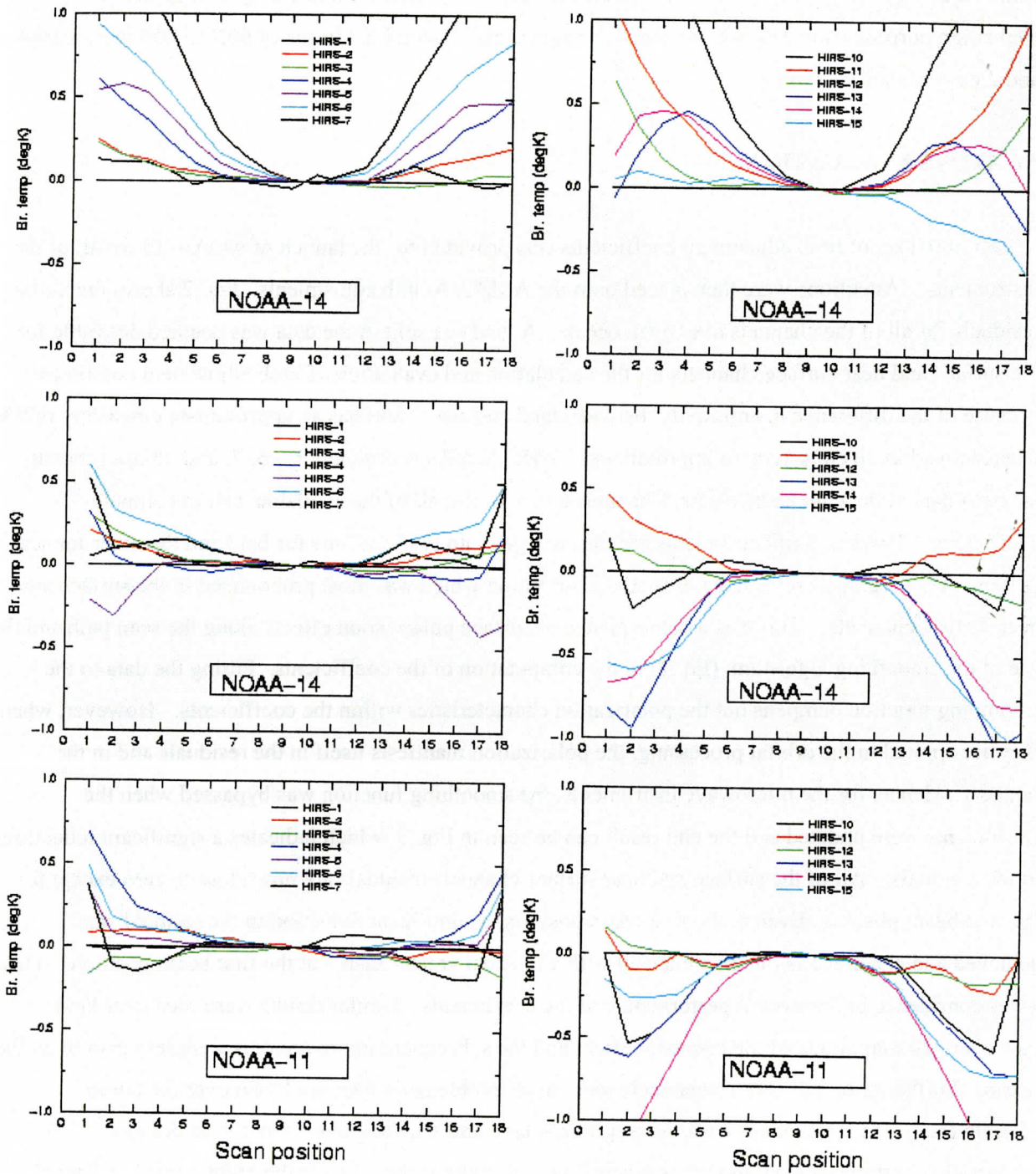


Fig. 1) ECMWF scan biases prior to limb adjustment coefficient update (top two plots May, 1998) and after update (bottom four plots, August, 1998).

Limb adjusted data came from the rotating orbital data files which contain 2.5 days of data. For evaluation purposes, the data was screened for high terrain, latitudinal limits of 60N to 60S were imposed and 2 days of data was used.

3.0 ATOVS EVALUATION

An initial set of limb adjustment coefficients was provided for the launch of NOAA-15 for all of the instruments. Attentions were then placed onto the AMSU-A limb adjustments. Fig. 2 shows the initial residuals for all of the channels over open ocean. A land/sea split in the data was deemed desirable for the surface and near surface channels for the calculation and evaluation of limb adjustment coefficients because of the difference in emissivity between land and sea. Land has an approximate emissivity of 0.9 whereas sea has an emissivity of approximately 0.45. AMSU-A channels 1 – 5, 7, and 15 use separate land/sea data to develop coefficients. Channels 6, 8 – 14 use all of the available data to compute coefficients. These sets of coefficients are then merged into two sets: one for land and the other for sea.

Plots of the residuals revealed a bi-modal distribution which was most pronounced in the surface and near surface channels. This was a consequence of surface polarization effects along the scan path and the use of the smoothing algorithm (Eq. 1) in the computation of the coefficients. Fitting the data to the smoothing function dampens out the polarization characteristics within the coefficients. However, when they are applied in the orbital processing, the polarization manifests itself in the residuals and in the imagery. Hence, for the microwave instruments, the smoothing function was bypassed when the coefficients were updated and the end result can be seen in Fig. 3, which indicates a significant reduction in the residuals. All of the surface and near surface channels residuals are now close to zero except for the first beam position. Even at the first beam position, a significant reduction in the residual was achieved and channel 1 is the only channel with a residual greater than 1 at the first beam position. This gives confidence in the overall performance of the coefficients. Similar results were seen over land. However, the magnitude of the bi-modal effect and the subsequent improvements were less than over the ocean. Furthermore, the surface channels seem more problematic over land than over the ocean.

Data for AMSU-A channel 7 was also split into land and sea components to derive the limb adjustment coefficients even though it is sensitive to the atmosphere above the 500mb level. Channel 7 imagery revealed a striping not found in the other channels across the scan. This striping amounts to an approximate temperature difference between adjacent beam positions of 0.2K. This is believed to be caused by data passing through the wrong oscillator. Splitting of the data into land and sea for limb correction coefficient generation alleviates some of the problem in the imagery.

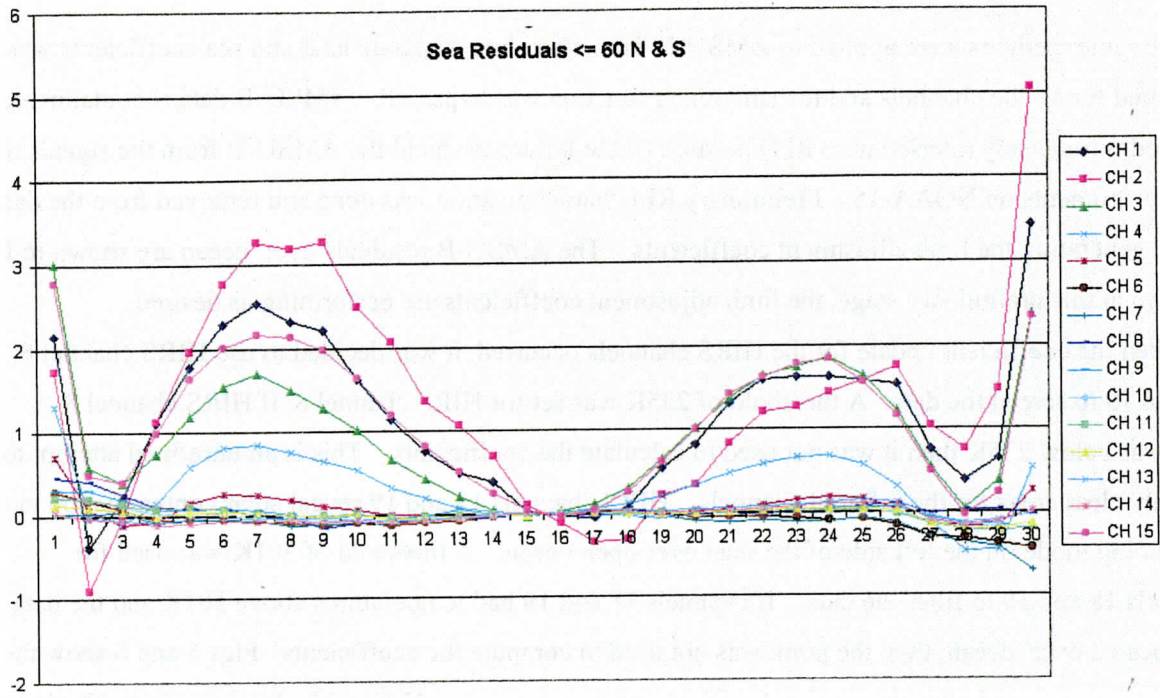


Fig. 2) AMSU-A initial sea residuals

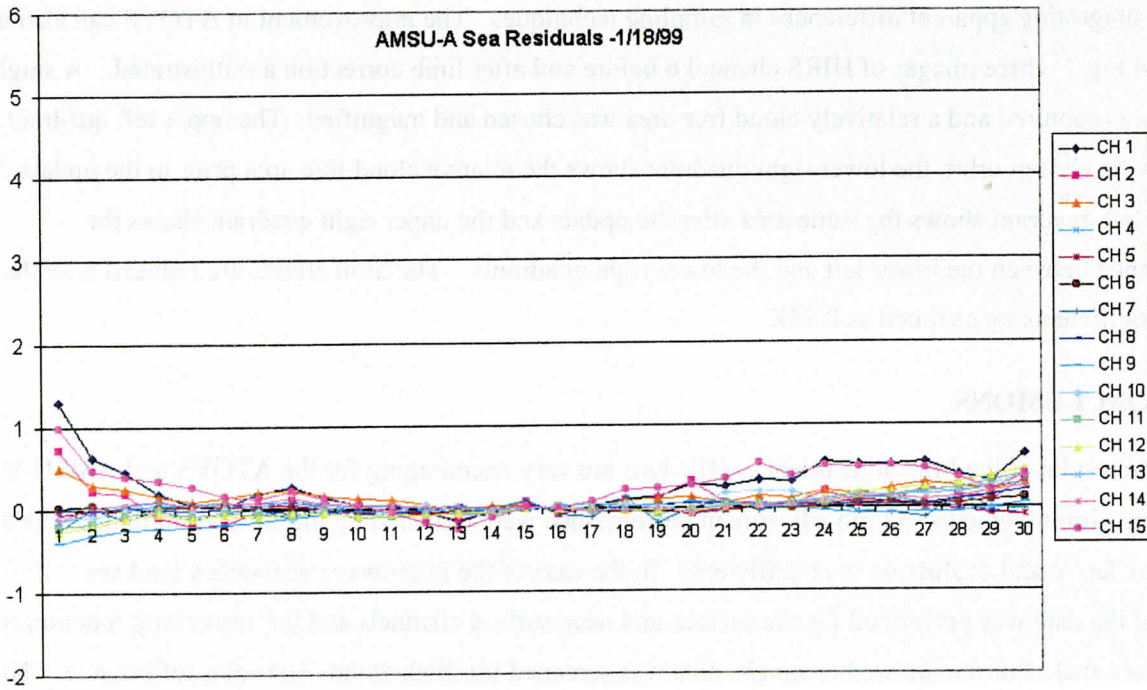


Fig. 3) AMSU-A sea residuals as of January 18, 1998

The same methods were applied to AMSU-B data. Therefore, separate land and sea coefficients were generated for all the channels and the smoothing function was bypassed. AMSU-B data is contaminated with radio frequency interference (RFI) because of the failure to shield the AMSU-B from the signals of other instruments on NOAA-15. Preliminary RFI characterization was done and removed from the data before generating the limb adjustment coefficients. The AMSU-B residuals over ocean are shown in Fig 4. Even at this preliminary stage, the limb adjustment coefficients are performing as desired.

When the coefficient update for the HIRS channels occurred, it was decided to use HIRS channel 8, 18, and 19 to screen the data. A threshold of 235K was set for HIRS channel 8. If HIRS channel 8 data was below 235K then it was not used to calculate the coefficients. This is an unrefined attempt to use only clear areas for the infrared channels. HIRS channels 18 and 19 reveal solar contamination in the descending mode on the left side of the scan over open ocean. A threshold of 301K was used for channels 18 and 19 to filter the data. If channels 18 and 19 had temperatures above 301K and the data was located over ocean, then the point was not used to compute the coefficients. Figs 5 and 6 show the residuals prior to and after the update, for the shortwave channels. Noticeable decreases in residuals are observed after the update. Similar results were observed in the other infrared channels (not shown). In general, channels 13, 14 and 15 residuals are much smaller than those observed in Fig. 1 for TOVS. Once again suggesting apparent differences in sampling techniques. The improvement in ATOVS can also be seen in Fig 7 where images of HIRS channel 6 before and after limb correction are illustrated. A single orbit was captured and a relatively cloud free area was chosen and magnified. The upper left quadrant shows the chosen orbit, the lower right quadrant shows the relative cloud free area prior to the update, the lower left quadrant shows the same area after the update and the upper right quadrant shows the difference between the lower left and the lower right quadrants. The limb effects are reduced with the new coefficients by as much as 0.75K.

4.0 CONCLUSIONS

The results of the limb adjustment coefficients are very encouraging for the ATOVS and AMSU-B systems. Improvements in limb adjustment performance were obtained by improved sampling of the data used to derive and evaluation the coefficients. In the case of the microwave channels a land/sea split of the data was performed for the surface and near-surface channels and the smoothing function was circumvented. For the infrared channels, data was screened for thick clouds and solar reflectance. Time of the data collection may also be a factor given the improvements seen in the TOVS where the only change was that data from a later time period was used to generate the coefficients implemented during

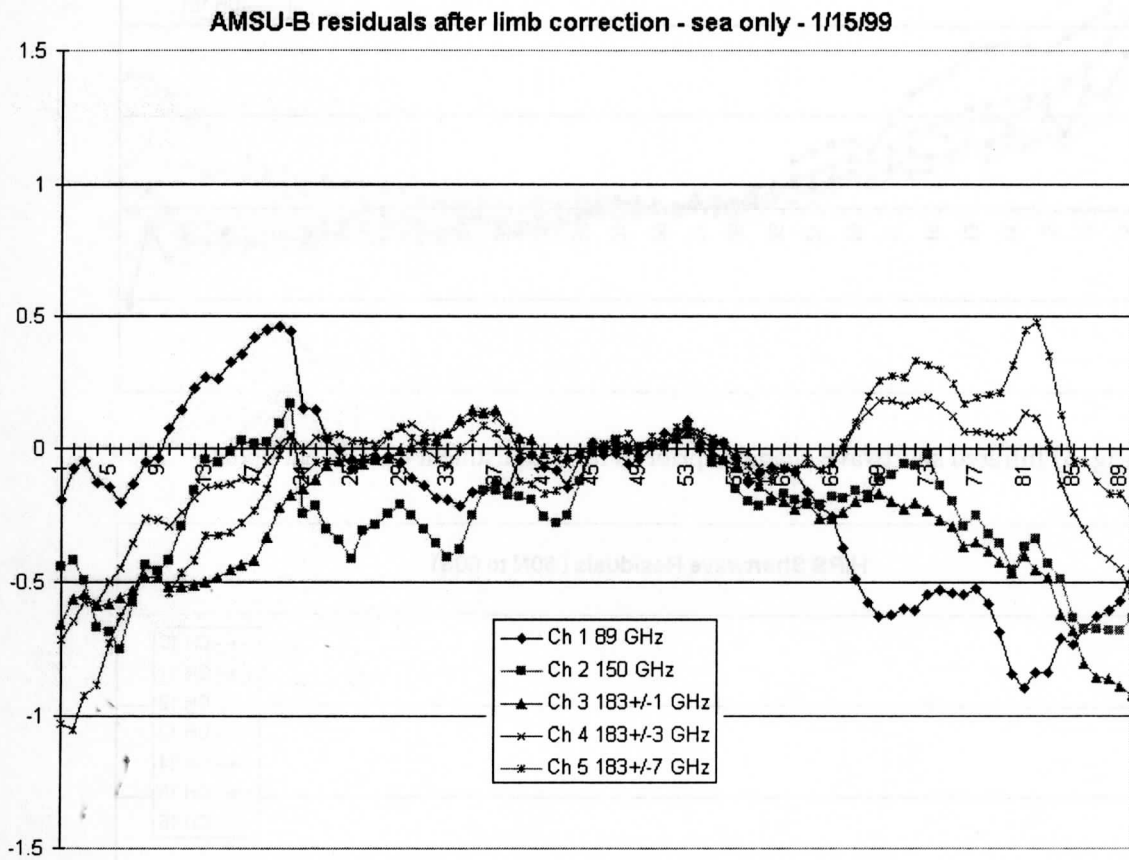


Fig. 4) AMSU-B sea residuals

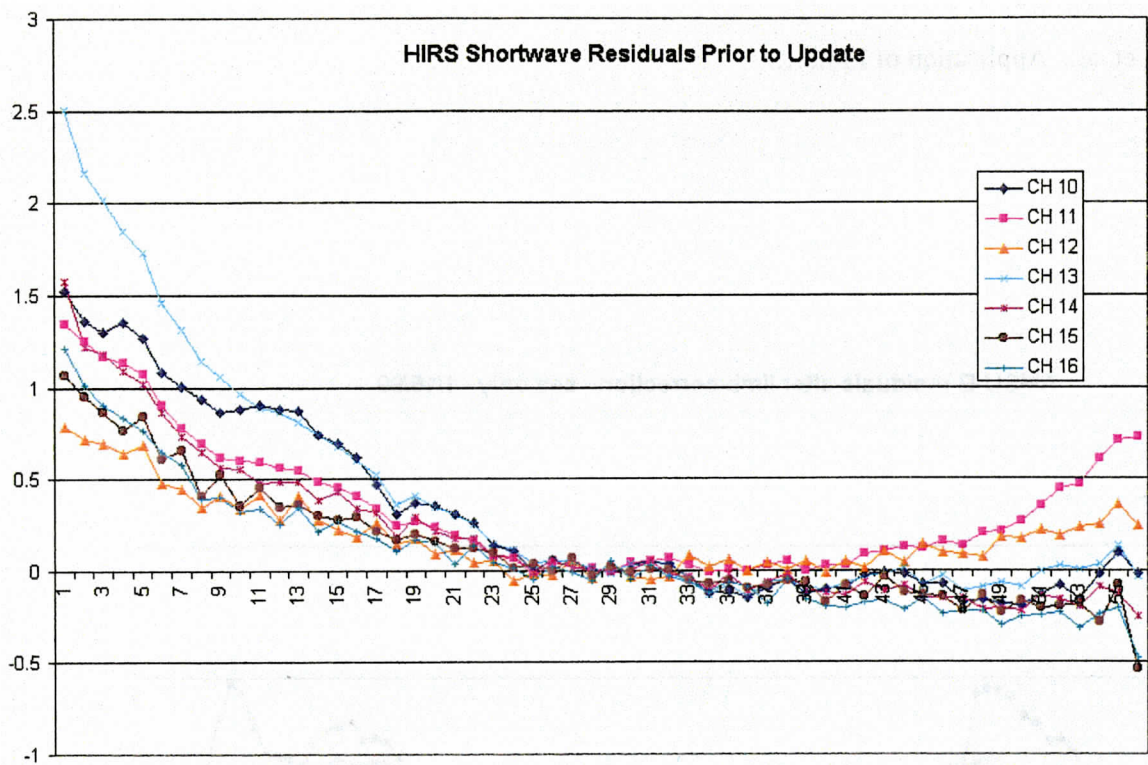


Fig. 5) Infrared shortwave channels prior to limb adjustment coefficient update

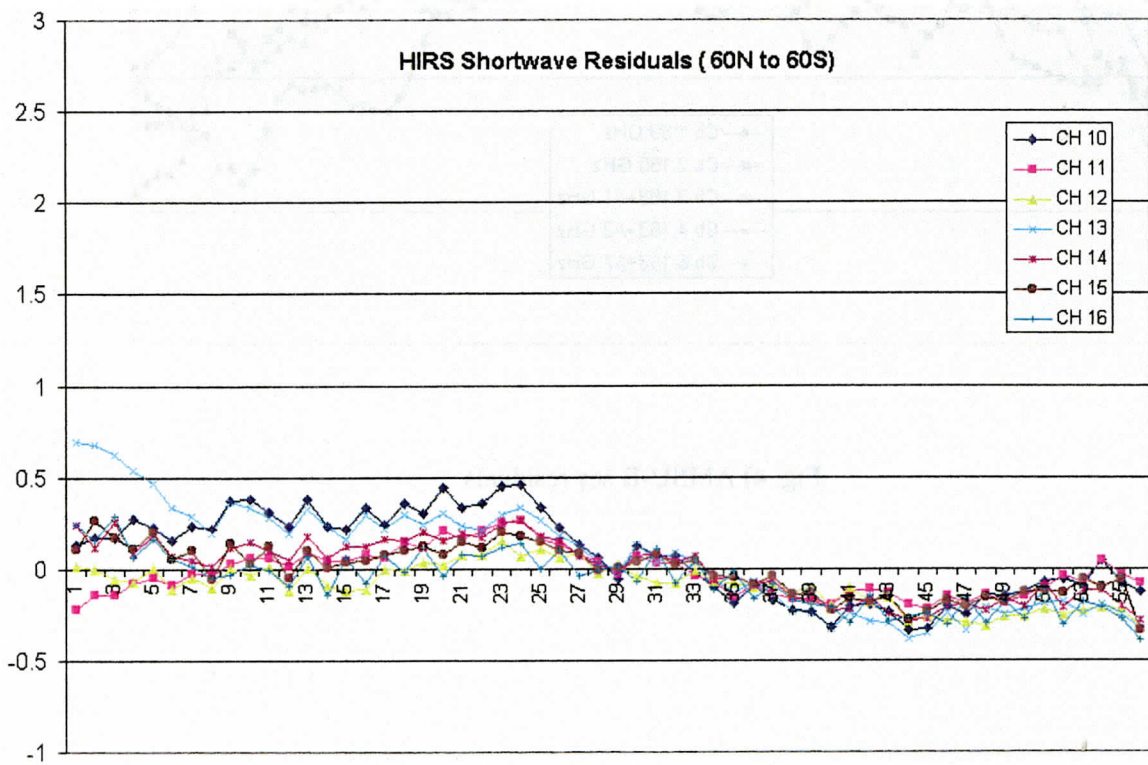


Fig. 6) Infrared shortwave channels after limb adjustment coefficient update

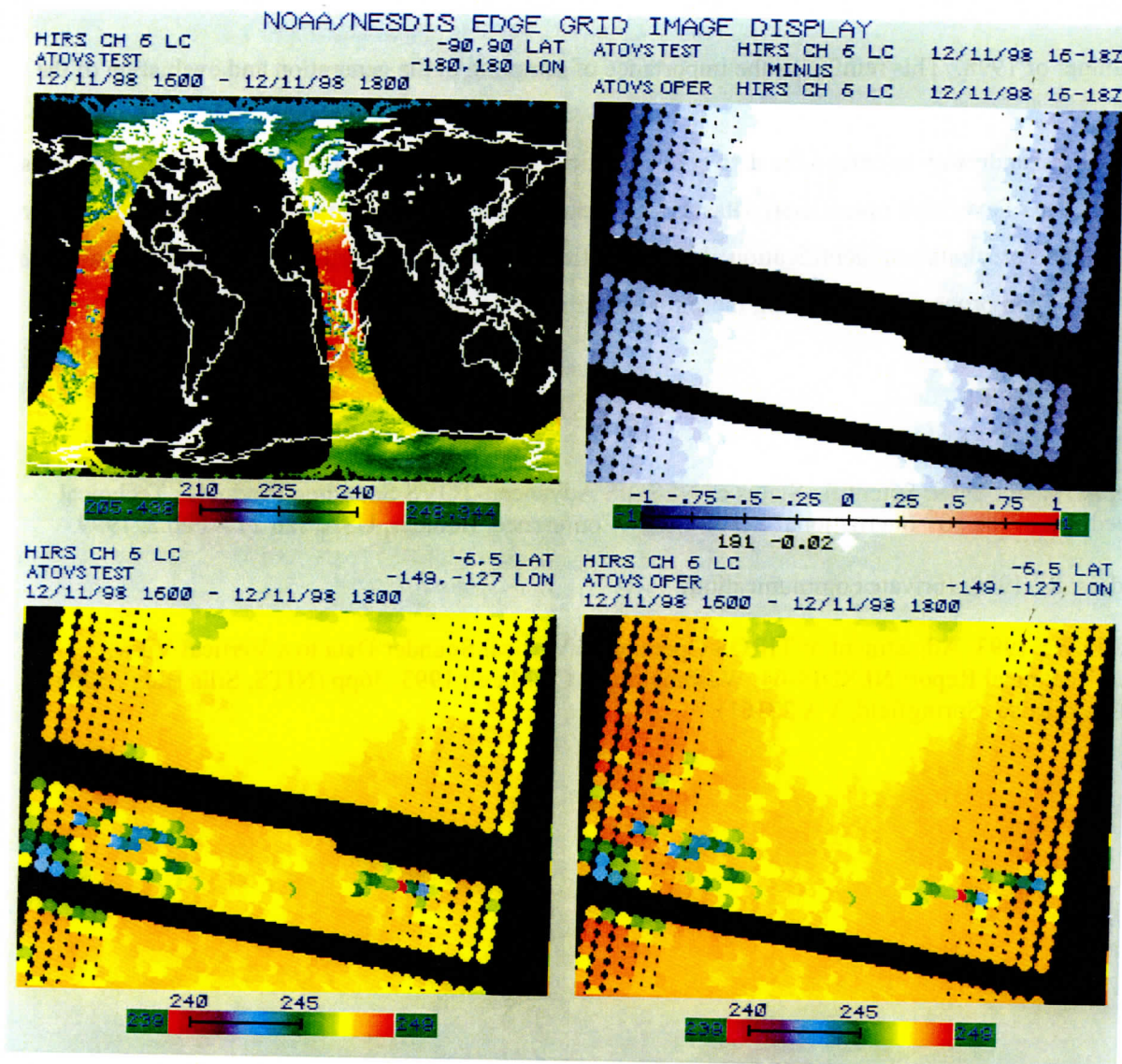


Fig. 7) HIRS channel 6 before and after coefficient update. Upper left shows the entire single orbit, lower left shows a relatively cloud free area, lower right shows the same cloud free area prior to the coefficient update and the upper right shows the difference between the lower left and lower right quadrants.

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the summer of 1998. This reinforces the importance of sampling in the generation and evaluation of the coefficients.

Efforts are underway to extend the data collection time period from the present 5 days to up to 60 days. Improved use of available operational datasets will enable better stratification of the data, including snow, ice, cloud and precipitation identification, during coefficient generation. Furthermore, this would also aid in the evaluation process by generating more robust statistics.

5.0 REFERENCES

Reale, A., et. al., 1999: Scientific Status of NESDIS Advanced-TOVS Sounding Products, Technical Proceedings of the 10th International TOVS Study Conference, Boulder, USA, Jan 27 – Feb 2, 1999.

Saunders, R., 1998: (private communication).

Wark, D.W., 1993: Adjustment of TIROS Operational Vertical Sounder Data to a Vertical View. NOAA Technical Report NESDIS-64, Washington, D.C., March 1993, 36pp (NITS, Sills Bldg., 5285 Port Royal Road, Springfield, VA 22161).

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