

**Global Background Characterization in 4.2-4.4 μm MWIR
by Using NOAA-12 Data**

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ABSTRACT

Background phenomenology databases and models are essential for the design and assessment of electro-optical sensing systems. The MWIR band has been proposed to satisfy a number of specific requirements in the DoD space based mission areas. However, the phenomenology database in the MWIR to support the design and performance evaluation is limited.

Currently the High Resolution Infrared Radiation Sounder (HIRS/2) onboard NOAA 12, an operational polar orbiting environmental and weather satellite, offers continual global coverage of several bands in the MWIR. In particular, Channel 17 operates in the heart of the 4.23 μm CO₂ band. Though with coarse resolution (~20 km), the vast database offers a good baseline understanding of the MWIR phenomenology related to space based MWIR systems on (1) amplitude variation as function of latitude, season, and solar angle, (2) correlation to relevant MWIR features such as high-altitude clouds, stratospheric warming, aurora and other geomagnetic activities, (3) identification of potential low spatial frequency atmospheric features, and (4) comparison with future dedicated measurements.

Statistical analysis on selected multiple orbits over all seasons and geographical regions was conducted. Global magnitude and variation in these bands were established. The overall spatial gradient on the 50 km scale was shown to be within sensor noise; this established the upper bound of spatial frequency in the heart-of-the-CO₂-band. Results also compared favorably with predictions from atmospheric background models such as the Synthetic High Altitude Radiance Code (SHARC-3.)

Keywords: MWIR Remote Sensing, Downlooking Earth Background, Clutter Characterization, Background Phenomenology

I. Introduction

The wings of the CO₂ MWIR band are being investigated for addressing DoD space based mission requirements. However, the phenomenology database in the MWIR to support design and performance evaluation is insufficient. Currently the High Resolution Infrared Radiometer Sounder (HIRS/2) onboard NOAA 12, an operational polar orbiting environmental and weather satellite, offers continual global coverage of several bands in the MWIR (Figure 1). The 20-channel HIRS/2 sounder was designed to provide global information on the vertical distribution of atmospheric temperature, moisture and cloud presence. In particular, Channel 17 operates in the heart of the 4.23 μm CO₂ band. Though with coarse resolution (~20 km), the vast database offers a good baseline understanding of the MWIR phenomenology related to (1) amplitude variation as function of latitude, season, and solar angles, (2) correlation to relevant features such as high-altitude clouds, aurora and other geomagnetic activities, (3) identification of potential low spatial frequency atmospheric features, and (4) comparison with future dedicated measurements.

In Section II, data processing and statistical analysis procedures are described. Section III presents the summary of the data, their means and variations, as well as the comparison with atmospheric structure model predictions.

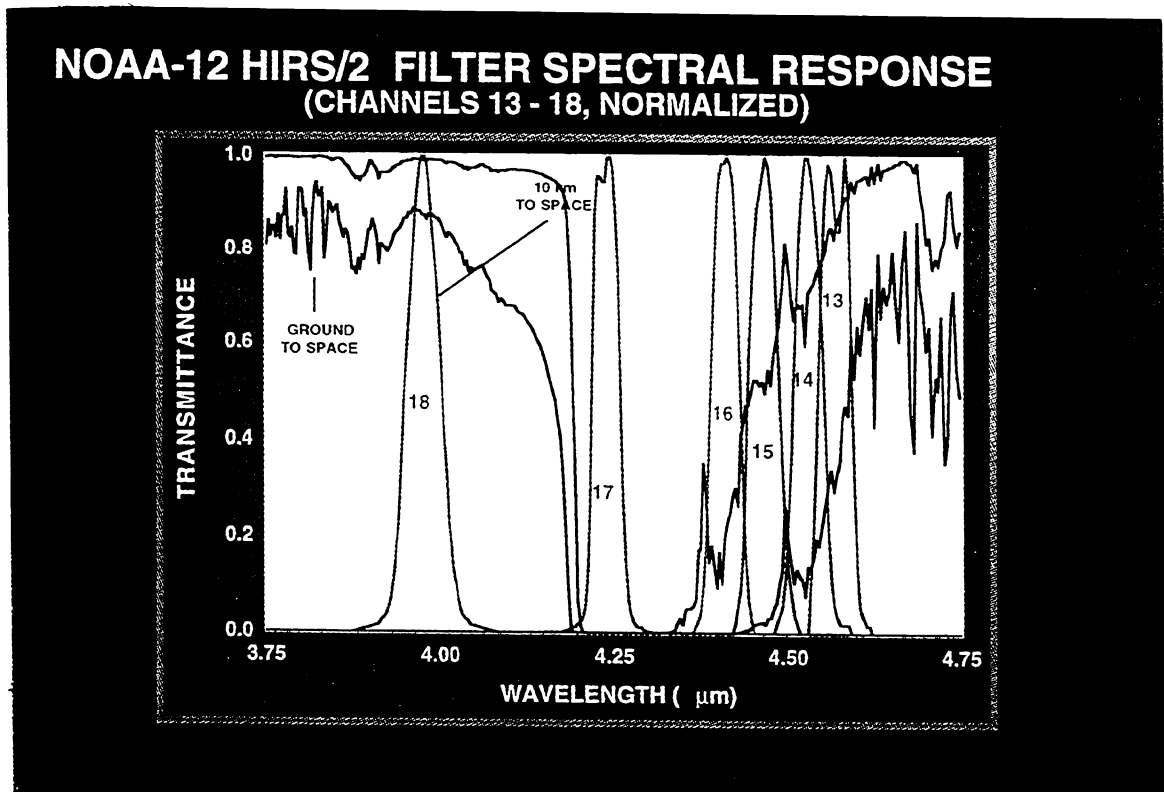


Figure 1

II. Data Processing and Analysis Approach

Various sets of HIRS/2 historical data were acquired through the National Climatic Data Center (NCDC). Thus far, four sets of 10-day global cumulative statistics were obtained and processed. Each set consists of 142 consecutive orbits; the first ten days of February, May, August and November 1995. Calibration and initial data quality check were conducted to ensure data applicability. For statistical analysis, data are limited to look angles from nadir to within 20 degrees off nadir such that uneven atmospheric attenuation effects are minimal and pixel size is smaller than 20 km by 20 km. Data were then binned to 1 deg by 1 deg in latitude and longitude grids.

Statistical analysis is then carried out which includes (1) the mean value of the ten-day samples; this establishes the global mean for each of the four seasons, (2) "temporal" standard deviation:

$$S.D. = \sqrt{N \Sigma I^2 - (\Sigma I)^2} / N \quad N = \text{all samples}$$

which represents single cell analysis of variation of brightness at all locations over a ten-day period, and (3) "spatial" standard deviation:

$$s.d. = \sqrt{n \Sigma I^2 - (\Sigma I)^2} / n \quad n = 9, \text{ and}$$

$$S.D. = \Sigma s.d. / N \quad N = \text{all samples}$$

which represents an average "in-scan" pixel-to-pixel variation within the 3 x 3 neighbors.

III. Highlights of Results

Some of the highlights of the statistical analysis results are presented here. Figure 2 illustrates the amplitude of HIRS/2 Channel 17 data for February, May, August and November. In both cases, the following can be concluded: (1) latitudinal variation is the most pronounced feature observed, (2) there is little longitudinal variation with respect to either geographical coverage or land/sea variation, and (3) the amplitude variation is generally monotonic with respect to latitude corresponding to the upper stratospheric thermal conditions.

Additionally, some stratospheric warming effects are also observed. The most evident is February in the >40 deg North Latitude and 70-135 deg East Longitude. Stratospheric warming is typically observed in January and February in the Northern Hemisphere at high latitude regions. Its persistent feature can last up to two weeks with temperature increase up to 60 deg in altitude region of 40-50 km and up to 100 km.

The range of HIRS/2 Channel 17 data is 3-12 $\mu\text{W}/\text{cm}^2\text{-sr-}\mu\text{m}$ for February, with the highest value in the Antarctic and decreasing toward the Northern Hemisphere. In

May the mean value ranges from 2 to 9 $\mu\text{W}/\text{cm}^2\text{-sr-}\mu\text{m}$, with the highest value in the Arctic region. Opposite geographical trends but with similar ranges as with February and May are observed for August and November, respectively (with the exception of November in the Antarctic where values greater than 15 $\mu\text{W}/\text{cm}^2\text{-sr-}\mu\text{m}$ were present.) These are consistent with the stratospheric thermal effect, a direct result of heating due to the absorption of solar ultraviolet radiation by ozone. A statistical representation of global zonal mean temperature is illustrated in Figure 3 for comparison.

Sample temporal and spatial standard deviation results (February and May) are shown in Figure 4. Range of temporal variation is typically $< 1 \mu\text{W}/\text{cm}^2\text{-sr-}\mu\text{m}$. In general, this represents the expected day-to-day variation. The spatial standard deviation results are indicative of the spatial "gradient" in approximately 100 x 100 km areas. Typical values are $\sim 0.05 \mu\text{W}/\text{cm}^2\text{-sr-}\mu\text{m}$.

Also conducted was the comparison with model prediction. An example of the Synthetic High Altitude Radiance Code (SHARC 3) model runs based on the Standard Atmosphere Generator (SAG) is demonstrated in Figure 5. Both nadir look and 45 deg look angle results for May are shown. The enhanced off-nadir values in the Northern Hemisphere are indicative of the non-local-thermal-equilibrium effect due to the coherent solar scattering. The agreement between data and model prediction is very good, within 20%, which confirms the capability of SHARC to predict the below-the-horizon (BTH) latitudinal and diurnal variations of the 4.23 μm mean radiance.

IV. Summary

A statistical analysis has been conducted of global MWIR data in the 4.23 μm region collected by an operational NOAA environmental and weather satellite. Initial effort includes the investigation of the global mean amplitude and standard deviations, both spatial and temporal, for all representative seasons. Results also compare favorably with model predictions. This work will be extended to analysis of other HIRS/2 bands that encompass the 4.2-4.4 mm spectral region. The data set is intended as part of the phenomenology database to aid in addressing various DoD space based system design and evaluation issues.

Acknowledgments

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*Ref. Middle Atmosphere Dynamics, by D.G. Andrews, J.R. Holton and C.B. Levoy, Academic Press, 1987

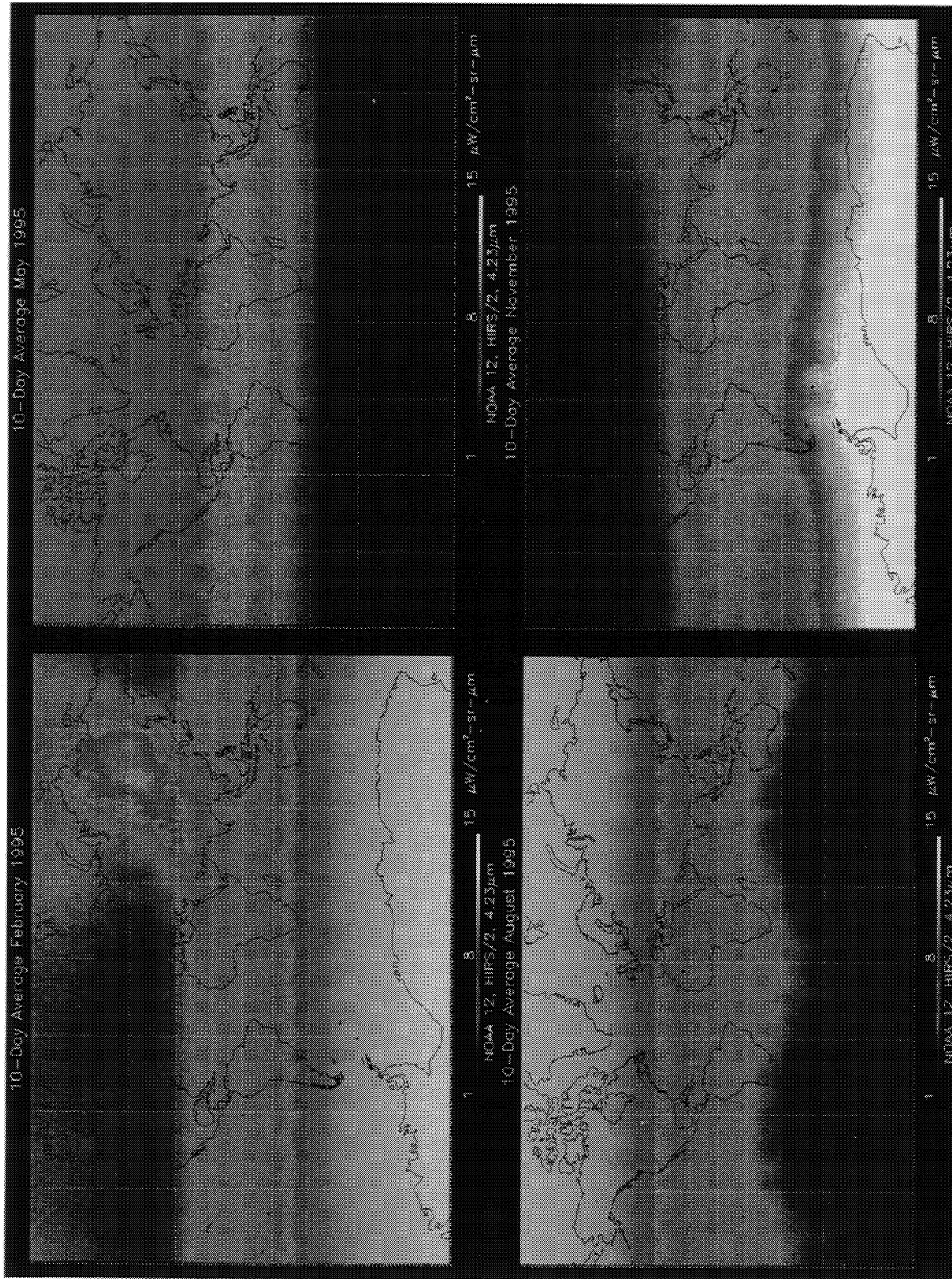
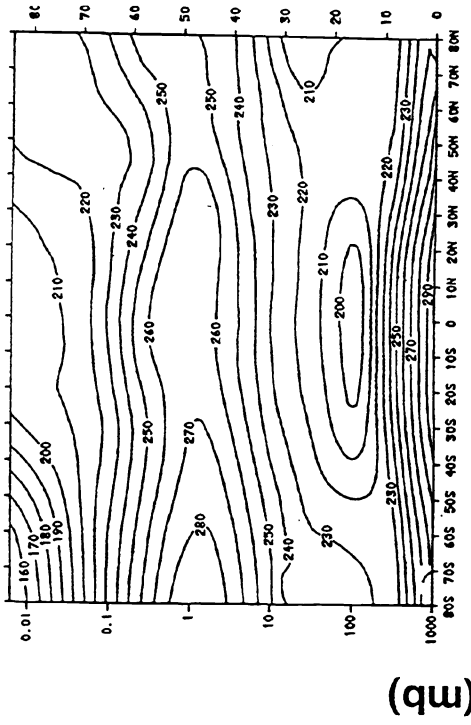


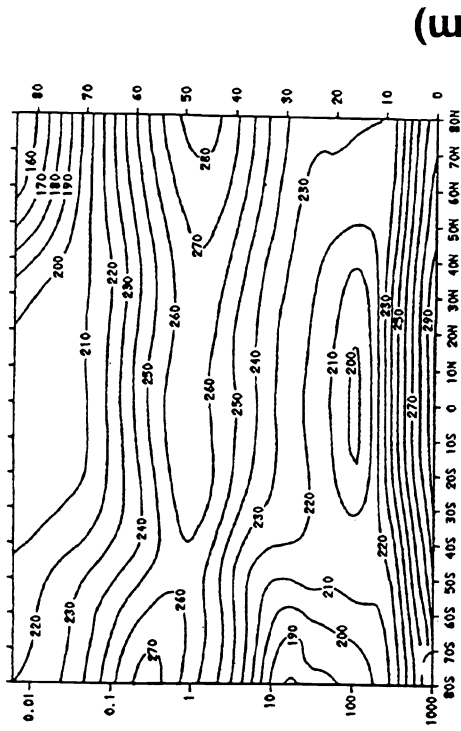
Figure 2 4.23 μm Global Averages for February, May, August and November

GLOBAL ZONAL MEAN TEMPERATURE

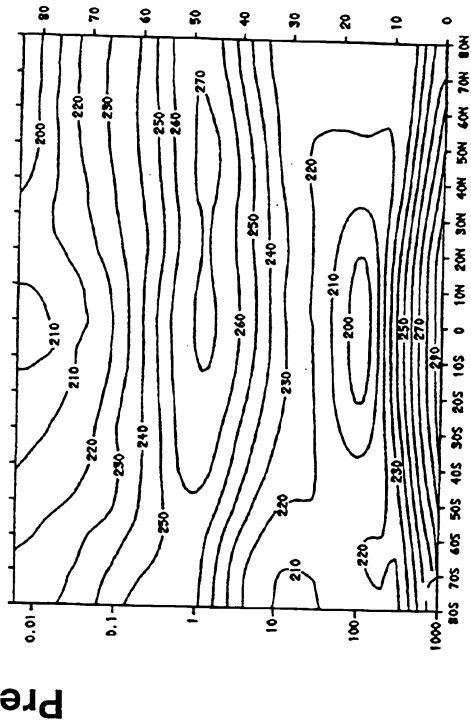
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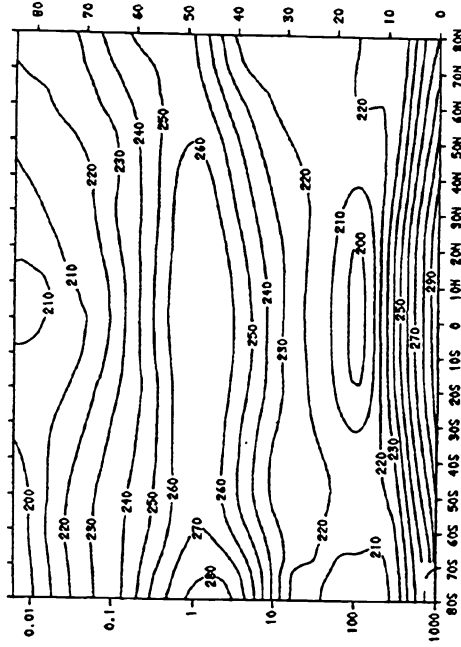
JULY



APRIL



OCTOBER



Latitude

Figure 3

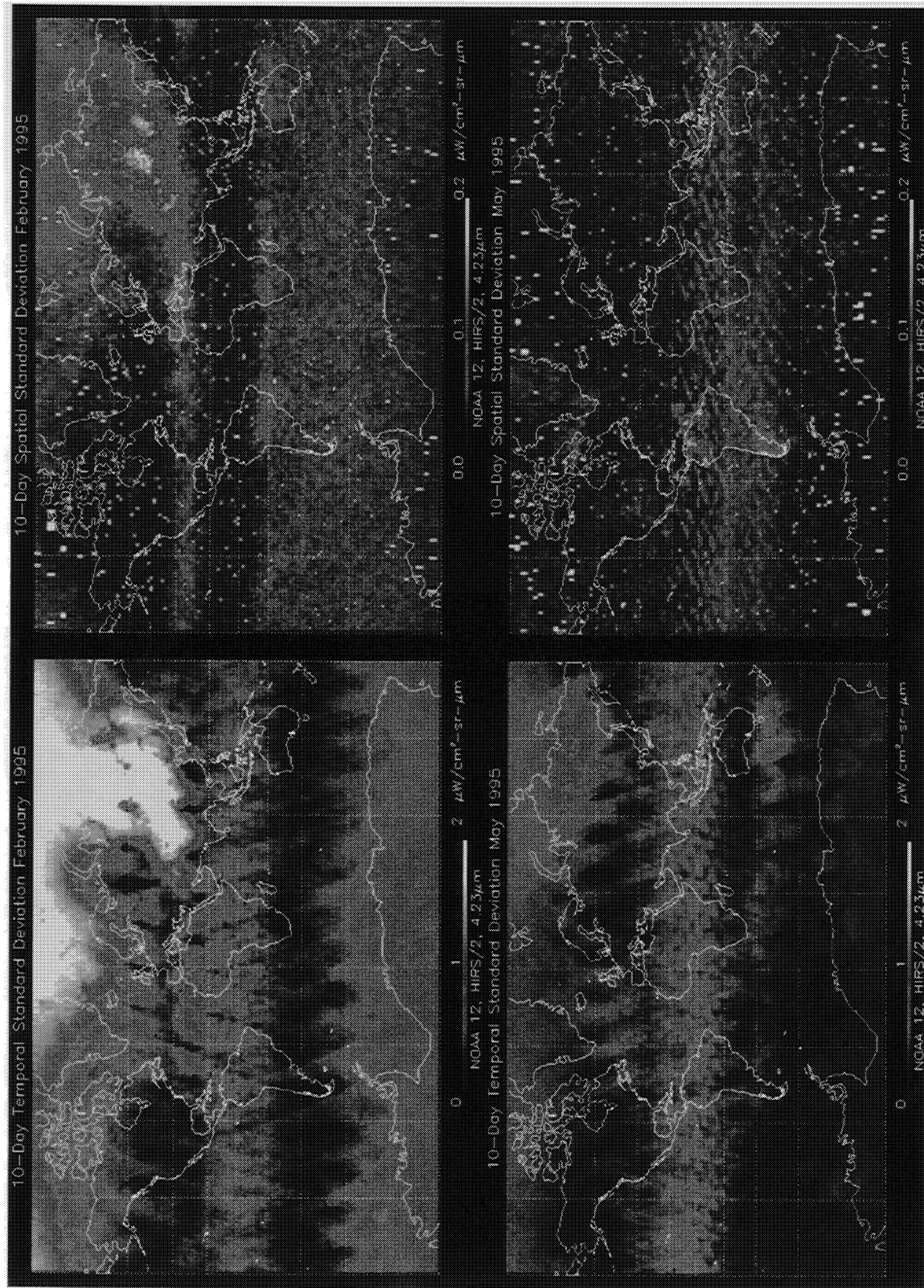
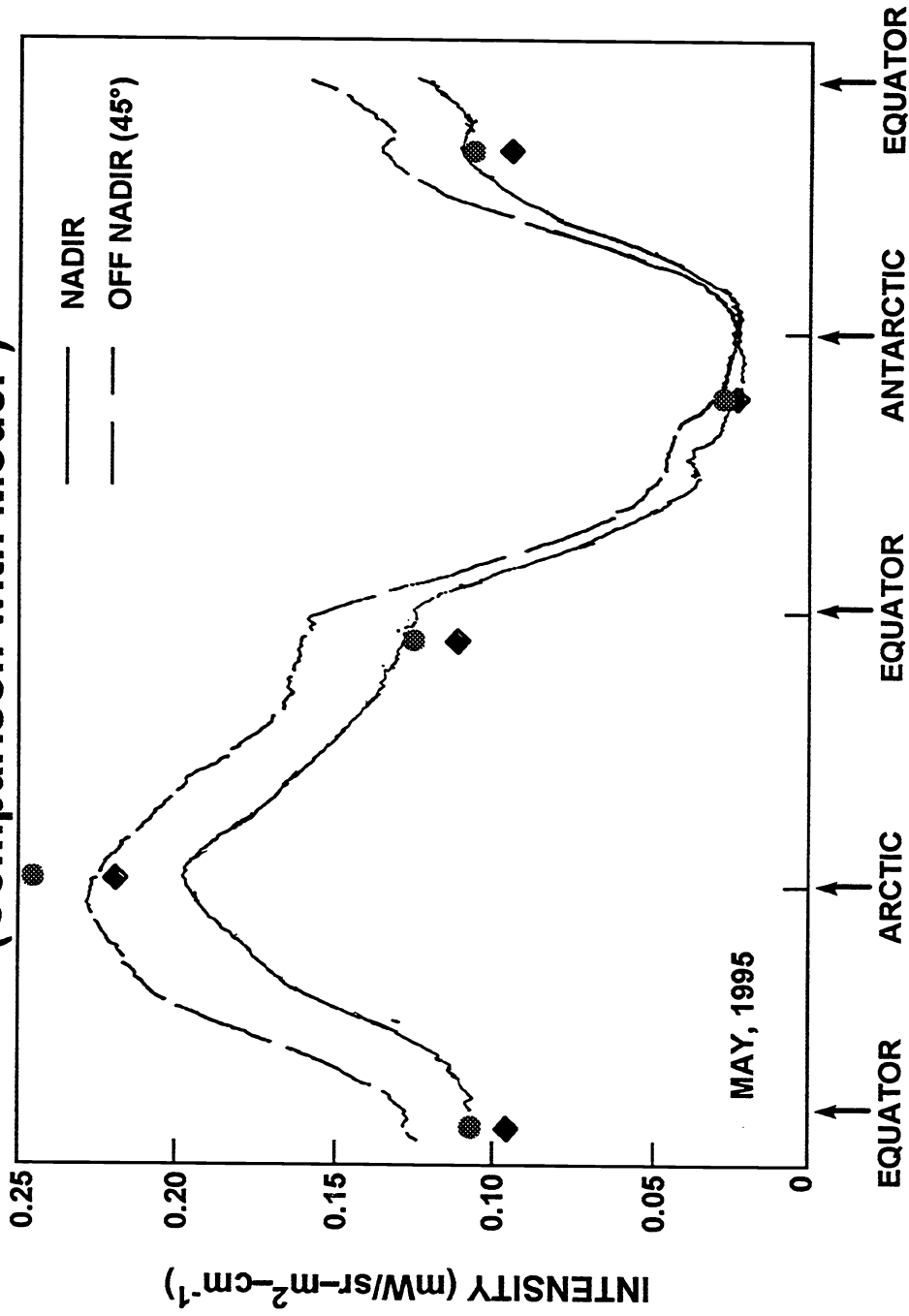


Figure 4 Temporal and Spatial Standard Deviations

NOAA 12 HIRS/2 DATA (4.23 μm) (Comparison with Model*)



MAY, 1995

*SYNTHETIC HIGH ALTITUDE RADIANCE CODE (SHARC 3)

Figure 5