# A CORRECTION TO THE DIURNAL SAMPLING BIAS IN HIRS OBSERVATIONS USING GFDL CLIMATE MODEL SIMULATIONS

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## INTRODUCTION

HIRS observations have in recent years been used for climate studies since they provide over 25 years of global observations of temperature, water vapor, ozone, clouds and OLR. HIRS instruments have flown on 13 different sun-synchronous satellites, and some of these satellites have drifted several hours from their original overpass times. Drifting satellites change the local time of observation and cause artificial trends in the data due to diurnal changes in temperature and clouds. Therefore, a technique has been developed to remove bias from HIRS observations affected by changes in diurnal sampling.

## DRIFTING SATELLITES

• Afternoon satellites (2 am/pm LCT overpasses) drift rapidly to later local times.
• Morning satellites (8 am/pm LCT overpasses) drift slowly to earlier local times.

HIRS/2 Local Ascending Equatorial Crossing Time

Morning Satellites

Afternoon Satellites

## HIRS/2 DATA

| NOAA Satellite | Time Period | Initial Ascending Crossing Time |
|---|---|---|
| NOAA-6 | 07/1979 - 03/1983 | 1930 LST (m) |
| NOAA-7 | 07/1981 - 01/1985 | 1430 LST (a) |
| NOAA-9 | 01/1985 - 09/1988 | 1420 LST (a) |
| NOAA-10 | 12/1986 - 08/1991 | 1930 LST (m) |
| NOAA-11 | 11/1988 - 12/1994 | 1330 LST (a) |
| NOAA-12 | 06/1991 - 03/1997 | 1930 LST (m) |
| NOAA-14 | 01/1995 - 12/2004 | 1330 LST(a) |

Note: TIROS-N and NOAA-8 data not used due to short lifespan of HIRS instruments

## DETECTION OF SAMPLING BIAS

• All-sky and clear-sky HIRS 1b data gridded onto $2.5^0$ monthly grids.
• Ascending and descending orbits averaged separately.
• Only average 6 scan positions closest to nadir.
• Anomalies constructed by subtracting first three harmonics computed for each satellite time series. Anomaly fields constructed using harmonic fields based on each satellite.
• GFDL AM2 3-hourly HIRS-simulated data were used to construct monthly model anomalies from the entire model field and from the HIRS-sampled model field.

### The Observed Bias

Ascending, descending, and combined anomalies of HIRS 11 $\mu$m channel indicate significant trends for the afternoon satellites.

### The Modeled Bias

Ascending and descending model anomalies correspond well with HIRS observed bias. Total anomaly time series shows no trend for any time series.

## CORRECTION METHOD

• Correction uses a three parameter exponential fit of the difference between the HIRS-simulated anomaly field and the total model anomaly field.
• The fit is a function of satellite, channel, latitude, surface type, local crossing time, and month.
• Maximum correction differences between first and last month of each satellite given in tables.
• Significant corrections mainly for afternoon satellites and lower tropospheric channels.

NOAA-14 11.1 $\mu$m 30N land-only

TOT-DSC RMS Diff = 1.11 K

TOT-ASC RMS Diff = 0.98 K

## SAMPLING BIAS SENSITIVITY

### Land vs. Ocean

30N-30S ASC 11.1 $\mu$m HIRS LAND-OCEAN

30N-30S DSC 11.1 $\mu$m HIRS LAND-OCEAN

### All-Sky vs. Clear-sky

30N-30S ASC 11.1 $\mu$m All-Clear

Solid = HIRS
Dashed = Model

30N-30S DSC 11.1 $\mu$m All-Clear

### Limb Effects

- Nadir observations use six FOVs nearest nadir.
- Far limb observations use six FOVs at left edge of swath.
- NOAA-14 time series indicates no difference in diurnal sampling bias between nadir and far limb observations

NOAA-14 30N-30S ASC 11.1 $\mu$m

Nadir
Far Limb

### Correction Difference 60N-60S

#### CLEAR-SKY LAND-ONLY

| Freq | N6 | N7 | N9 | N10 | N11 | N12 | N14 |
|---|---|---|---|---|---|---|---|
| 14.7 | 0.02 | -0.03 | 0.02 | -0.08 | -0.01 | -0.14 |
| 14.5 | 0.02 | -0.03 | 0.01 | -0.07 | -0.01 | -0.13 |
| 14.2 | 0.01 | 0.00 | -0.02 | -0.02 | -0.06 | -0.01 | -0.01 |
| 14.0 | 0.00 | 0.07 | 0.08 | -0.07 | 0.15 | -0.06 | 0.36 |
| 13.7 | 0.01 | 0.20 | 0.25 | -4.13 | 0.51 | -0.18 | 1.43 |
| 13.4 | 0.03 | 0.50 | 0.61 | -0.28 | 1.32 | -0.52 | 3.22 |
| 11.1 | 0.05 | 1.24 | 1.54 | -0.57 | 3.51 | -1.15 | 8.18 |
| 9.7 | 0.03 | 0.72 | 0.91 | -0.27 | 2.04 | -0.68 | 4.97 |
| 8.3 | 0.04 | 0.98 | 1.28 | -0.49 | 2.68 | -0.93 | 6.23 |
| 7.3 | 0.02 | 0.05 | 0.12 | -0.04 | 0.23 | -0.04 | 0.52 |
| 6.7 | -0.01 | -0.02 | 0.02 | 0.02 | 0.02 | 0.00 | -0.06 |

#### CLEAR-SKY OCEAN-ONLY

| Freq | N6 | N7 | N9 | N10 | N11 | N12 | N14 |
|---|---|---|---|---|---|---|---|
| 14.7 | 0.02 | -0.02 | -0.02 | 0.00 | -0.04 | 0.00 | -0.08 |
| 14.5 | 0.01 | -0.02 | -0.02 | 0.01 | -0.04 | 0.00 | -0.08 |
| 14.2 | 0.01 | -0.02 | -0.02 | 0.01 | -0.04 | 0.00 | -0.05 |
| 14.0 | 0.00 | 0.00 | 0.01 | -0.01 | -0.01 | -0.02 | 0.05 |
| 13.7 | 0.00 | 0.04 | 0.04 | -0.02 | 0.07 | -0.05 | 0.26 |
| 13.4 | 0.02 | 0.09 | 0.11 | -0.05 | 0.23 | -0.12 | 0.61 |
| 11.1 | 0.03 | 0.24 | 0.29 | -4.11 | 0.68 | -0.42 | 1.63 |
| 9.7 | 0.02 | 0.14 | 0.17 | -0.07 | 0.38 | -0.14 | 0.92 |
| 8.3 | 0.02 | 0.20 | 0.24 | -0.10 | 0.51 | -0.19 | 1.24 |
| 7.3 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| 6.7 | 0.02 | -0.02 | -0.02 | 0.01 | 0.02 | 0.00 | -0.06 |

**Bold** indicates significant adjustments
Shaded indicates afternoon (2 pm ASC) satellites
Brightness temperatures in units of Kelvin

## SENSITIVITY OF CORRECTION

ASCENDING LAND-ONLY OBSERVATIONS

### CHANNEL SENSITIVITY

NOAA-14 Tb Corrections    December 2004    NOAA-14 RMS Error

ALL-SKY

ALL-SKY

CLEAR-SKY

CLEAR-SKY

### TIME SENSITIVITY

NOAA-14 11 $\mu$m Correction

### SATELLITE SENSITIVITY

11 $\mu$m Anomaly of First Month

## CORRECTION RESULTS

• Corrected HIRS anomaly data has diurnal bias removed.
• HIRS 11 $\mu$m brightness temperature trend reduced over subtropics.

### NOAA-14 11 $\mu$m Trends

Uncorrected
Corrected

30N-30S ASC 11.1 $\mu$m HIRS corrected anomalies

30N-30S DSC 11.1 $\mu$m HIRS corrected anomalies

30N-30S ASC+DSC 11.1 $\mu$m HIRS corrected anomalies

Solid = HIRS
Dashed = Model

## CONCLUSIONS

• The effects of diurnal sampling bias on HIRS observations can be modeled by GFDL climate model simulations.
• Diurnal sampling bias is greatest for afternoon satellites, observations over land, and observations near the surface.
• Diurnal sampling bias shows insignificant dependence on scan angle.
• Diurnal corrections show significant latitudinal dependence due to high amplitude diurnal fluctuations over the subtropical desert regions.
• All-sky and clear-sky corrections show only small differences in the amplitude of their corrections.
• New correction method removes trends in HIRS observations caused by diurnal sampling bias.