LOCKHEED MISSILES AND SPACE COMPANY

A Subsidiary of Lockheed Corporation

ENGINEERING MEMORANDUM

TITLE: PRELIMINARY SURFACE TEMPERATURE REQUIREMENTS ANALYSIS	EM NO. 1147 REF: SOW 3.3
PREPARED BY: C.R. Kenley CHECKED BY: D. Paul	DATE: 11 November 1994 APPROVAL: M. Whitten

PURPOSE:

The purpose of this Engineering Memorandum (EM) is to develop parametric analysis of Sea Surface (SST) and Land Surface Temperature (LST) EDRs versus E/O sensing measurement accuracies.

APPROACH:

A literature search of SST and LST algorithm performance using either actual or simulated data was performed. For SST, the McClain, et al, 1983 results presented in Advanced Space Research, Vol. 2, No. 6, were used for the baseline For LST the Axelsson 1985 results presented at the Nineteenth Symposium on Remote Sensing of Environment in Ann Arbor Michigan, were used. The point results in these papers were parameterized using first-order multiple linear regression error analysis to study the impact of changes in channel measurement accuracy on surface temperature EDR estimation accuracy.

SUMMARY AND CONCLUSION:

For sea surface temperature, a system specification minimum requirement of 0.5 K 1-σ error in SST is unachievable using our 11 and 12 micron IR channels in daytime. At night time, a minimum requirement is achievable with a 1-σ sensor measurement error of 0.1 K at 3.7 microns and 0.1 K at 11 and 12 microns. A goal of 0.25 K error in SST is unachievable.

For land surface temperature, a requirement of 1.5 K 1-σ error in LST is achievable with a 1-σ sensor measurement error of 0.25 K at 11 and 12 microns, assuming a 1-σ knowledge error of 1.02 in surface emissivity.

DISCUSSION:

The discussion covers the two EDRs studied:

1. Sea Surface Temperature (SST)
2. Land Surface Temperature (LST)

1. Sea Surface Temperature

From Table 1 of McClain's results the RMSD (Root Mean Square Difference) between observed and predicted SST in day time is 0.78 K using the 11-12 micron "split window" estimation equation for AVHRR measurements

$$T_{4/5} = 1.035\ T_{11} + 3.046\ (T_{11} - T_{12}) - 283.93.$$

The reported AVHRR 1-σ sensor measurement error in both the 11 and 12 micron band is 0.1 K. Using first-order error analysis, there is an error due to the uncertainty in the bands and a residual or unexplained error due to modeling error (nonlinearity and other effects). It can be expressed as

$$0.78^2 = residual_{4/5}^2 + (1.035\ \sigma_{11})^2 + (3.046\ \sigma_{11})^2 + (3.046\ \sigma_{12})^2.$$
$$0.78^2 = residual_{4/5}^2 + (1.035 \times 0.1)^2 + (3.046 \times 0.1)^2 + (3.046 \times 0.1)^2.$$
$$residual_{4/5} = 0.591.$$

Thus, for any given 11 and 12 micron band error, the daytime SST error is estimated by

$$\sigma_{SST}^{day} = \sqrt{0.591^2 + (1.035\ \sigma_{11})^2 + (3.046\ \sigma_{11})^2 + (3.046\ \sigma_{12})^2}.$$

The RMSD between observed and predicted SST at night time is 0.58 K using the 3.7-12 micron "split window" estimation equation for AVHRR measurements

$$T_{3/4/5} = 1.060\ T_{11} + 1.038(T_{3.7} - T_{12}) - 289.55.$$

The reported AVHRR 1-σ sensor measurement error in both the 11 and 12 micron band is 0.1 K and is 0.3 K in the 3.7 micron band. Thus,

$$0.58^2 = residual_{3/4/5}^2 + (1.060\ \sigma_{11})^2 + (1.038\ \sigma_{3.7})^2 + (1.038\ \sigma_{12})^2.$$
$$0.78^2 = residual_{3/4/5}^2 + (1.060 \times 0.1)^2 + (1.038 \times 0.3)^2 + (1.038 \times 0.1)^2.$$
$$residual_{3/4/5} = 0.466.$$

For any given 3.7, 11 and 12 micron band error, the night time SST error is estimated by

$$\sigma_{SST}^{night} = \sqrt{0.466^2 + (1.060\ \sigma_{11})^2 + (1.038\ \sigma_{3.7})^2 + (1.038\ \sigma_{12})^2}.$$

If the 11 and 12 micron error are assumed to be equal, the parametrics are as shown in Figure 1.

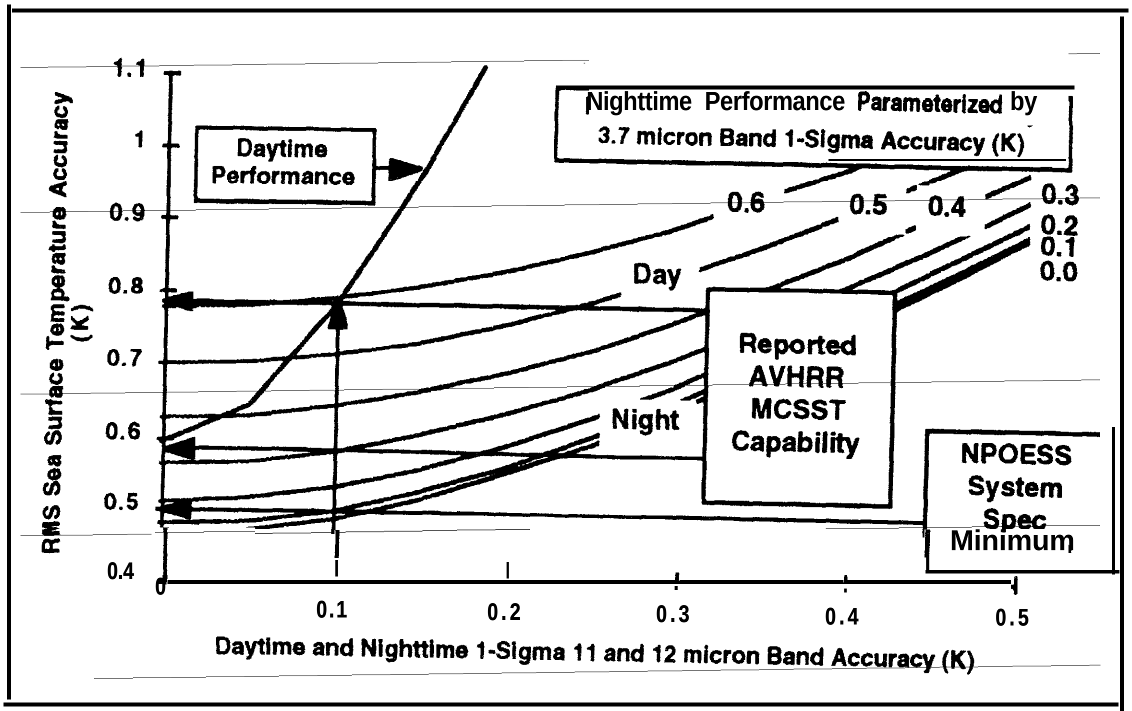

Figure 1. Sea Surface Temperature Parametrics for AVHRR Bands

Since, the 11 and 12 micron bands are assumed to have the same values in Figure 1, the day time performance is a single curve. The night time performance is a family of curves parameterized by the 3.7 micron accuracy. For sea surface temperature, a system specification minimum requirement of 0.5 K 1-σ error in SST is unachievable using our 11 and 12 micron IR channels in daytime. At night time, a minimum requirement is achievable with a 1-σ sensor measurement error of 0.1 K at 3.7 microns and 0.1 K at 11 and 12 microns. A goal of 0.25 K error in SST is unachievable.

2. Land Surface Temperature

From Tables I and II of Axelsson's results the RMSD (Root Mean Square Difference) between observed and predicted LST is characterized as a function of the standard deviation of the a ***priori*** knowledge of surface emissivity and the assumed correlation between the emissivity in the 11 and 12 micron bands. For perfect knowledge of the emissivity ($\sigma_\varepsilon = 0.0$) and no correlation between the 11 and 12 micron emissitivity ($\rho_\varepsilon = 0.0$) the error in LST is 0.48 K using the 11- 12 micron estimation equation

$$LST = 3.477\, T_{11} - 2.425\, T_{12} - 12.5,$$

where the result in degrees Celsius. The reported AVHRR 1-σ sensor measurement error in both the 11 and 12 micron band is 0.1 K. Applying the same approach as for SST,

$$0.48^2 = residual^2 + (3.477\ \sigma_{11})^2 + (2.425\ \sigma_{12})^2.$$

$$0.48^2 = residual^2 + (3.477 \times 0.1)^2 + (2.425 \times 0.1)^2.$$

$$residual = 0.225$$

For any given 11 and 12 micron band error, the LST error for this case is

$$\sigma_{LST} = \sqrt{0.225^2 + (3.477\ \sigma_{11})^2 + (2.425\ \sigma_{12})^2}\ .$$

Other cases for emissivity knowledge and correlation were considered by Axelsson. Applying the first-order error analysis equations in a similar fashion yields the parametrics shown in Figure 2.

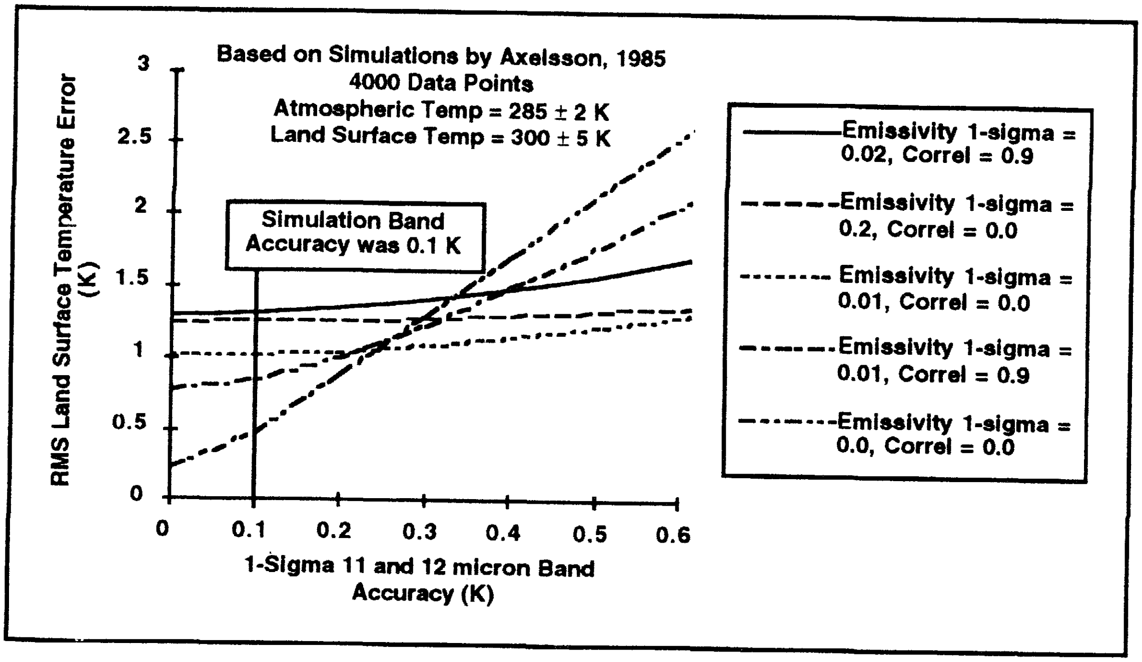

Figure 2. Land Surface Temperature Parametrics for AVHRR Bands

As the *a priori* uncertainty in emissivity increases from 0.0 to 0.02 in Figure 2, the RMS LST error increases as long as the measurement accuracies are less than approximately 0.25 K. Beyond 0.25 K, the curves start to cross over and yield non-intuitive results. This is because the RMS LST error is a first-order approximation expanded about a measurement accuracy of 0.1 K, and the accuracy of the approximation degrades when applied too far from the expansion point. A requirement of 1.5 K 1-σ error in LST is achievable with a 1-σ sensor measurement error of 0.25 K at 11 and 12 microns, assuming a 1-σ knowledge error of 0.02 in surface emissivity.