Quarterly Report

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A) Near-term Objective

To develop and validate an atmospheric radiative transfer model in the thermal infrared range from 10 to 13 microns which is accurate enough for development of land-surface temperature (LST) algorithms at the specified accuracy level for EOS.

B) Task Progress

1. The atmospheric radiative transfer code ATRAD has been ported from SUN workstations to a new IBM RISC/6000 320H workstation. After some modifications including effective use of main memory for quick calculations in multiple boundary conditions, the computational efficiency is nearly doubled. The overall performance of ATRAD on the IBM workstation is 10 times faster than the performance on the original SUN 3/60 workstation. Therefore, multiple scattering radiative transfer simulations could be made at a higher spectral resolution and with more molecular absorptions terms.

2. A series of simulations have been made by using the ATRAD code with new exponential-sum-fit tables at a spectral interval of 5 cm^-1 based on molecular band absorption coefficients used in LOWTRAN 7 and MODTRAN codes. The results have been also compared with those from LOWTRAN6, LOWTRAN7 and MODTRAN with respect to effects of different approximations (such as the two-stream method, the k-distribution multiple scattering method and the Curtis-Godson approximation) and different absorption coefficients used in LOWTRAN and MODTRAN codes.

3. Because the wide used McClain's split-window SST algorithm is based on regression analysis of many coincident satellite and drifting buoy measurements, it could be used to validate radiative transfer methods and to evaluate the effect of variations in molecular absorptions on surface temperature determinations. Assuming that the band brightness temperatures for AVHRR channel 4 and 5 located in the

10-13 micron wavelength range have a same accuracy, a simple error analysis shows that the SST error is about as 6.2 time larger as the error in the band brightness temperature in the worst case. According to this relation, the accuracy of band brightness temperature should be 0.05K and 0.16K, for pixel temperature determinations, in order to reach the specified sea-surface temperature (SST) accuracy 0.3K and LST accuracy 1K, respectively. This corresponds to accuracies of 0.07% and 0.23%, for the band averaged radiance used in SST and LST algorithms at around 300 K, respectively. For the triple-window algorithm, the accuracy might be relaxed by a factor of about 2. Therefore, the required radiance accuracy for radiative transfer simulations is at the 0.1% level and ranges from 0.1% to 0.5%. A series of factor analyses indicate that in the 10-13 micron range this accuracy can be achieved marginally only by ATRAD, an accurate multiple scattering radiative transfer model using exponential-sum-fit tables for accurate molecular absorption coefficients.
When we apply the above error analysis to MODIS thermal band data, it is obvious that the requirement 0.05K for specification of noise equivalent differential temperature (NEDT) could not be relaxed in order to achieve the SST and LST accuracies.

4. Pursuant to the suggestion which Dr. David Rosten, Ressler Associates Inc. made last year after his efforts for my search of thermal infrared spectroradiometer, I kept constant communications with Dr. Daniel Ng at NASA Lewis Research Center for planning use of the spectroradiometer there for spectral emissivity measurements of land surface materials. We have discussed technical details and experiment plans via electronic mail. It has been planned to do laboratory and some field measurements at the Lewis Research Center during April 5-12 just before the MODIS Science Team meeting at NASA/GSFC, April 13-16, 1992 for saving my travel expense.

C) Anticipated Activities During the Next Quarter

1. More work will be done in the 8-9.2 micron range where one MODIS thermal band and three ASTER bands are designed for surface temperature and emissivity analysis. First of all, exponential-sum-fit tables will be formulated based on molecular band absorption models in MODTRAN. Then a series of radiative transfer simulations will be made in this range. The work will be also extended to the 3.5-4.2 micron range after a few months.

2. Theoretical analysis of the spectral radiance data collected

at the Lewis Research Center will be made to extract spectral emissivities by using radiative transfer simulations for correction of the environmental radiance effect on emissivity determinations.

3. To prepare drafts of Software and Data Management Plan and Science Computing Facility Plan both due June 1992.

D) Problems/Corrective Actions

The CO_2 absorption models in MODTRAN and LOWTRAN7 are so different that the difference between their transmission functions could be more than 20% at wavelengths by 4.1 and 13 microns. In MODTRAN, the CO_2 continuum (tail contributions from lines beyond 25 cm^-1) has been mixed into the line tail absorption coefficient band model parameter C (usually for tail contributions from lines within +- 25 cm^-1).

So far the exponential-sum-fit tables used in ATRAD for CO_2 and O_3 are still based on data used in LOWTRAN7. Only the H_2O band model in MODTRAN has been adopted and translated into a new exponential-sum-table for ATRAD simulations. This results in a best agreement with McClain's split-window SST algorithm. For the "standard" tropical atmospheric condition used in LOWTRAN7 and MODTRAN codes, the SST difference between the value given by the algorithm and the input value is -0.05K according to the ATRAD result. It is -0.52K and 0.87K for results from LOWTRAN7 and MODTRAN, respectively.

A solution for CO_2 absorption will be made after comparing MODTRAN with fast line by line models FASCOD2 and FASCOD3P. It will take a quite long time. A possible better option under consideration is to follow similar procedures for H_2O absorptions, i.e., to deal with band and continuum absorptions separately.