INTRODUCTION

Increases in the concentrations of atmospheric gases that absorb thermal radiation ("greenhouse gases") result in a climate system response, a change of temperature fields to compensate for the increased atmospheric opacity. The conventional measurement used in climate change study has been surface air temperature ($T_s$) obtained from the WMO stations (Jones et al. 1999), which represents some combination of the surface radiative temperatures and that of the overlying ocean. Measurements of surface radiative temperature from satellite, i.e. skin temperature ($T_s$), can be more directly interpretable in terms of the surface response to increases of greenhouse gases (Jia and Dickinson 2001).

NOAA polar-orbiting satellites have monitored skin temperature using AVHRR for more than twenty years. This global observation has spatial resolution of 1 Km at nadir, samples twice daily. Unfortunately, this observation cannot be directly used in studies of global climate change because of the problems of satellite orbit drift, cloud contamination, and lack of diurnal cycle information. Corrections for these problems have been developed to reduce such errors (Jia and Dickinson 1999, 2000, Gutman 1999, Jia 2000, Jia and Treadon 2001) and to produce a diurnal cycle data set for land surface skin temperature (referred to as "LSTD"). Inferral from the thermal emission of terrestrial surfaces, LSTD are some

combination of vegetation canopies and soils. The data set includes the 24-hour average, maximum, and minimum values of diurnal cycle, and are tabulated at monthly intervals and 8 Km resolution. This data set provides an independent source of information regarding global changes of surface temperature over the last two decades. The stand deviation of individual monthly average values are estimated to be about 1 to 2 C and to include spatially varying biases because of variations in surface emissivity and other such factors. However, such biases are largely reduced when studying anomalies.

DATA EVALUATION

It is essential to validate LSTD before applying it in studies of climate change. Due to the lack of other independent, long-term, high resolution, global observations, NCEP reanalysis, which is physically consistent, is considered as the most helpful data to examine the spatial and temporal variations of LSTD (Kalnay et al. 1996).

Figure 1 is the climatology of diurnal averaged skin temperature for July. The data are averaged from 1981-1996 at half degree resolution which is scaled up from original 8 Km. The snow-covered areas such as southward of 60°S are not retrieved. Comparison with the NCEP reanalysis shows encouraging consistency between these two data. More importantly, satellite data present more spatial structures of temperature with details valuable for studies of regional climate. Figure 2 compares zonal mean AVHRR-based $T_s$ with NCEP reanalysis for July 1997 (upper panel) and July 1988 (lower panel), for land areas only. Ev-
Identically, the two agree with each other very well except at the tropical areas. The large discrepancies in the tropics are partly due to the imperfect first guess field of the assimilation scheme (Trembath et al. 2001), and partly due to the problems of AVHRR $T_a$ retrieval at arid areas. The agreements of 1988 and 1997 indicate that the quality of the data is generally reliable for most land areas in El Nino and La Nina events.

RESULTS

Figure 3 compares the anomalies of global mean satellite $T_a$, WMO $T_a$, and NCEP reanalysis of $T_a$. An obvious positive trend during the study period is observed from these three surface temperature data sets. Satellite AVHRR $T_a$ has increased at 0.43 C/decade, while the rates for $T_a$ and NCEP $T_a$ are 0.28 C/decade and 0.34 C/decade, respectively. The consistency of satel-
Figure 5:

1. The $T_v$ and NCEP/NCAR reanalysis suggests that
   a warming does occur during 1961-1996. In addition,
   the exact rate of increase depends on how global
   and annual averages are calculated.

2. Seasonality and latitude-dependence are also evident from LSTD. Figure 4 is the seasonal
   mean $T_v$ anomalies during 1981-1996, for 20N
   and 60-80N respectively. Although in July the
   variations of $T_v$ are not as significant as in January
   (not shown), low latitudes have larger variations
   of $T_v$ than that of high latitudes. This is the same
   result as reported from GCM (Schneider and Dickin-
   nson, 1974), implying a positive lapse rate feed-
   back.

3. Land-biosphere-atmosphere interactions are responsible for global and regional climate
   changes. High resolution satellite data makes it
   possible to study the variation of $T_v$ over different
   land cover. Figure 5 is $T_v$ anomalies over desert
   and semi-desert areas at low latitudes. Al-
   though the trend may not be statistically signifi-
   cant, desert areas show larger interannual varia-
   tions than those of other areas. Furthermore, the
   diurnal range of skin temperature decreases during
   1982 to 1996 (Fig. 5 lower panel), which is similar
   to the global averaged result.

ACKNOWLEDGEMENT This
work is funded by NASA EOSDIS program under
contract NAG-99-EPA.

REFERENCES

Gutman, G. 1999: On the use of land surface tem-
peratures with the NOAA/AVHRR: rem-
oving the effect of satellite orbit drift,

Jones, P. D., M. New, D. E. Parker, S. Martin,
and I. G. Briffa, Surface air temperature
and its changes over the past 150 years.

Jia, M. and R. E. Dickinson, 1999: Interpo-
lation of surface radiation temperature
measured from polar orbiting satellites to

ized Algorithm for Retrieving Cloudy Sky
Skin Temperature from Satellite Thermal
Infrared Radiance. J. Geophys. Res.,
105, 27037-27047.

Jia, M., 2001: Interpolation of surface radiation
temperature measured from polar orbit-
ning satellites to a diurnal cycle. Part 2:
Cloudy-pixel Treatment. J. Geophys.

Jia, M. and S. Coates, 2001: A Note on Land
Surface Temperature: Definitions, Simu-
lations, and Application to Land Surface
to JGR.

the Orbit Drift Effect on AVHRR Skin Tem-
perature Measurements. submitted to
JGR.

for Global Warming From Satellite. re-
vised for GRL.

Kalnay, E. and co-authors, 1996: The
NMC/NCAR 40-year reanalysis project.

Tremberth, K. E., D. P. Stepaniak, J. W. Hurrell,
2001: Quality of reanalyses in the Tropics.
J. Climate, 14, 1499-1510.

Schneider, S. H. and R. E. Dickinson, 1974: Clima-
tine Modelling, Reviews of Geophysics
and Space Physics, 12, 447-486.