Annual Report on NASA Grant

Inter- Annual Land Surface Variation

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Introduction

This first period of operations has concentrated on establishing the techniques and data sets needed to undertake an accurate study of inter annual variation. The 20 year NOAA AVHRR data set has been intensively studied, and we have detected some problems with the thermal channels. These problems relate to the slowing in orbit of successive satellites following launch with the effect that the observations of the surface occur later in the day when the land surface has cooled. This effect has not been commented upon extensively since the thermal bands are more commonly used to observe the oceans where cooling is less obvious. We have therefore developed a correction scheme for the Pathfinder AVHRR Land (PAL) data (Gleason et al., 2001). In addition we have extended the soil moisture algorithms in the GLO-PEM model and have completed a new 20-year, 10 day, 8km resolution run, which is being prepared for publication. This run has been compared with the results of a more detailed mechanistic biogeochemical model (CEVSA), and the results are encouraging. Finally we have used the Simple SiB soil-vegetation- atmosphere-transfer model together with AVHRR surface variables for Africa and have examined the impacts of measured surface variables on heat and moisture fluxes. These results have shown consistent differences from those obtained using the standard land surface variable look up tables. Because of these differences, we have run a coupled GCM with the new land surface data and we are comparing the anomalies with standard runs.

The next step in the work will be to undertake change detection studies with the improved net primary production and surface flux data that have been prepared in the first year.

I. Effects of Orbital Drift on Land Surface Temperature Measured by AVHRR Thermal Sensor

The NOAA series of meteorological satellites that carry the Advanced Very High Resolution Radiometer (A VHRR) suffer from orbital drift so that during each satellite's duty period the overpass time occurs later in the day. Replacement satellites restore the overpass time temporarily but then it gradually decays. We have documented the effects of variable observation time owing to orbital drift on brightness temperatures (BT) and land surface temperature (LST) calculated from them in the NOAA/NASA Pathfinder AVHRR Land (PAL) data set and have considered possible corrections for the resulting trends and discontinuities in the PAL BT data. The drift effects were found to be greater for bare ground than for vegetated land cover classes, however significant effects were found for most vegetated classes. The magnitude of the orbital drift effect for most global cover types was at least as large as the other errors that affect LST measurement. A simple empirical correction for observation time based on solar zenith angle was used to correct the PAL BT time series following Gutman (1999). The correction from this method was compared with that predicted by a physically based model and was found to differ in the early part of each satellite's duty cycle. Finally the impacts of correction on the effective observation time were analyzed and the simple statistical correction was found to suffer from greater variability than has hitherto been recognized. A modification to the statistical correction to adjust the effective observation time was developed (Gleason et al., 2001).

2. Satellite-detected inter annual variations in terrestrial net primary productivity

Inter annual variability and long-term trends in terrestrial net primary productivity (NPP) are of great importance to quantifying the terrestrial carbon sink. We have estimated the global inter annual variation in terrestrial NPP from 1981 to 2000 by running our GLObal Production Efficiency Model (GLO-PEM, Prince and Goward, 1995) with the Pathfinder AVHRR data at a resolution of 10km and 10 days (Agbu and James, 1994). GLO-PEM is unique in that it is driven entirely with satellite-derived biological and climate variables and has built-in algorithms to remove satellite orbital drift effects on the thermal channels (Prince and Goward, 1995; Goetz et al. 2000; Cao et al. 2001, Gleason et al., 2001) so that it can produce high-resolution, temporally consistent estimates of NPP using the data from various NASA/NOAA meteorological satellite platforms.

Our estimated global NPP (Figure 1) exhibited a pronounced seasonal cycle with great inter annual variability. Superimposed on the inter annual variability in NPP was a clear cycle related to El Niño Southern Oscillation (ENSO). NPP generally decreased with strong El Niño events (e.g. in 1983 and 1987) and increased in normal years or the years with moderate La Niña events (e.g. in 1984, 1994, and 1996). However, the responses to individual El Niño or La Niña events depended on the actual sign, magnitude and spatial pattern in the changes in temperature and precipitation they brought about. While the correlation between NPP and temperature was strong throughout Eurasia and North America, the inter annual anomalies in NPP in the South America, Southeast Asia, Australia, and Africa were closely linked to variations in precipitation.

The low estimate of NPP for 1991 and 1992 was related to a abrupt plunge in the satellite measurements of the Normalized Vegetation Index (NDVI) caused by aerosol scattering from the Mount Pinatubo eruption that, on the one hand, weakened vegetation signals reaching the satellite sensor, and, on the other hand, actually reduced NPP due to the resultant cooling and reductions in incident photosynthetically active radiation.

Figure 1. The estimated seasonal and inter annual variations in NPP with the GLO-PEM model and AVHRR data. NPP anomalies were calculated as the difference between NPP for a given 10-day and the average value for the 10-day between 1981 and 2000. The El Nino Southern Oscillation (ENSO) is represented as the multivariate ENSO index (Walter and Timlin, 1998).

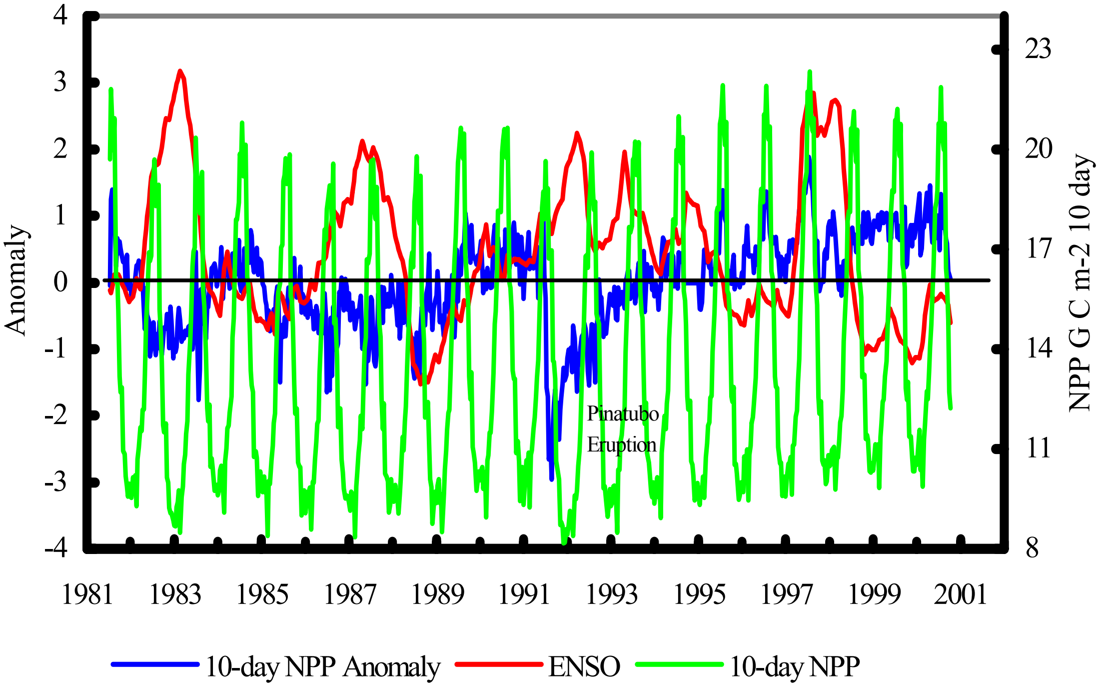
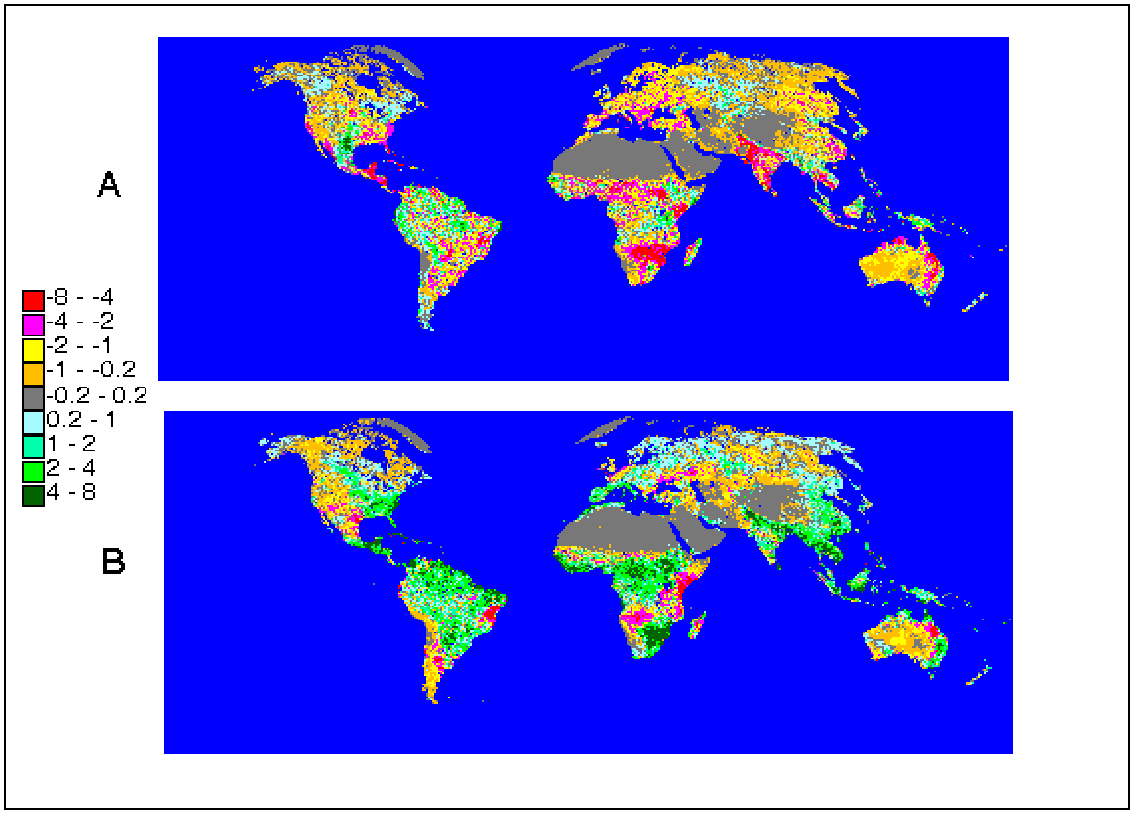


Figure 2. The estimated NPP anomalies (g C m-~ per 10 day) for 1987 (A) with strong El Nino events and for a normal year (1996). The NPP anomalies were calculated as the difference between NPP for a given year and the average value between 1981 and 2000.



Our calculated NPP for later 1990s are higher than the average value for the 1980s, supporting the estimates of increasing terrestrial carbon sequestration in the 1990s (IPCC, 2000). However, our estimated increased in the 1990s were caused by temporary increases in rainfall. Our results did not show a consistent increasing trend as other studies have done using ecophysiological models (Cao et al. 1998) or analyzing NDVI data (Myneni et al. 1997). To reveal the changing trend of NPP requires longer time-series data, it therefore is imperative to establish a sustained NPP observation program.

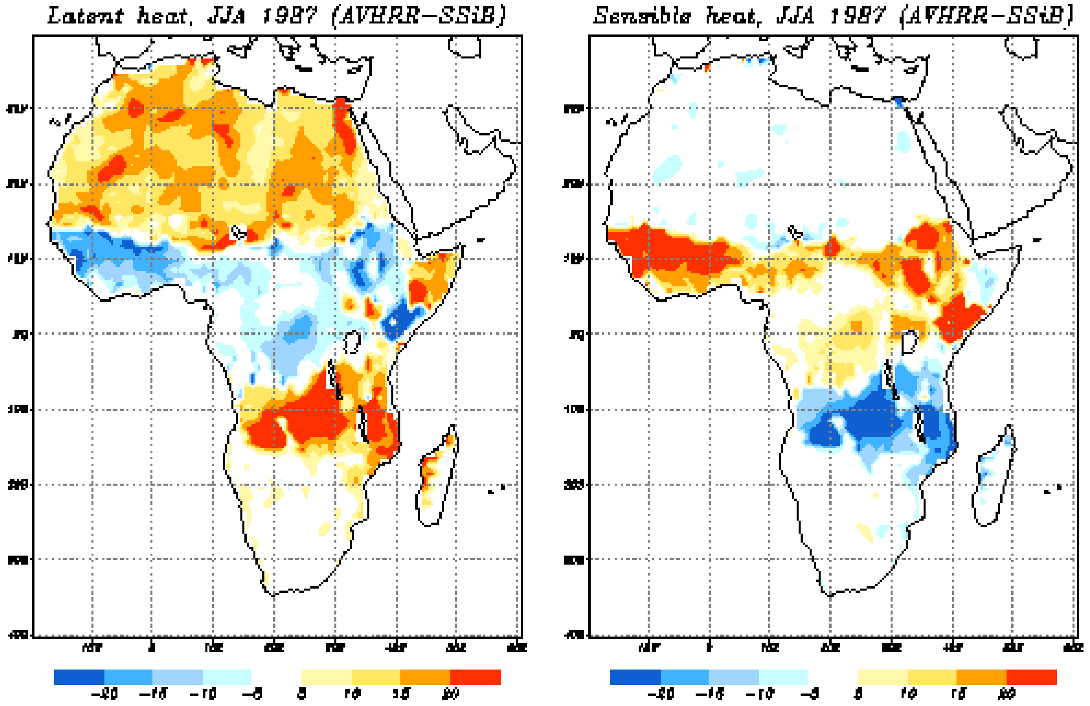
3. Sensitivity studies of Africa climate to land surface variables

The land-atmosphere interaction is an important area of climate research. To study the impact of land surface parameters to the regional climate in Africa, we have conducted off-line tests using Simplified Simple Biosphere Model (SSiB) (Xue, 1991), the International Satellite Land Surface Climatology Project (ISLSCP) Initiative I data, and the high resolution AVHRR land cover data.

The atmospheric forcing, including air temperature, radiation, wind, humidity and pressure, were derived from the ISLSCP data set on each 1 x 1 degree cell over the African continent for 1987-88. The land cover data, including leaf area index (LAI), green canopy fraction and vegetation cover were aggregated from AVHRR satellite data according to the vegetation types that SSiB model used (Borak, 2001). The sensitivity analysis was undertaken by running the SSiB model with two sets of land cover parameters, one from traditional land survey and another from the AVHRR data. The results show that the observed changes of land cover parameters affected the distribution of latent and sensible heat over the whole Africa continent, especially in central and southern Africa (Figure 3), the simulated seasonal patterns of surface temperature, soil moisture and runoff were also changed.

We are now conducting simulations using SSiB coupled with the National Center for Environmental Prediction (NCEP) general circulation model (GCM). The preliminary results shows that the results of the on-line running are consistent with the off-line tests.

Fig.3 Differences of simulated latent and sensible heat between using AVHRR observations and standard data.



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