2 Generation of time series of evaporative fractions and relative soil moisture

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2.1 Huabei plane

In China, shortages of fresh water and food resources in 21st century may become very serious. The Huabei plane, located in the Northern part of China is one of the most important grain crop producing areas. These regions belong to semi-arid climate region. Water resources is the key factor for agricultural development and the need for quantitative information on the water balance will increase the areas. Therefore the Huabei plane is choosen as study object.

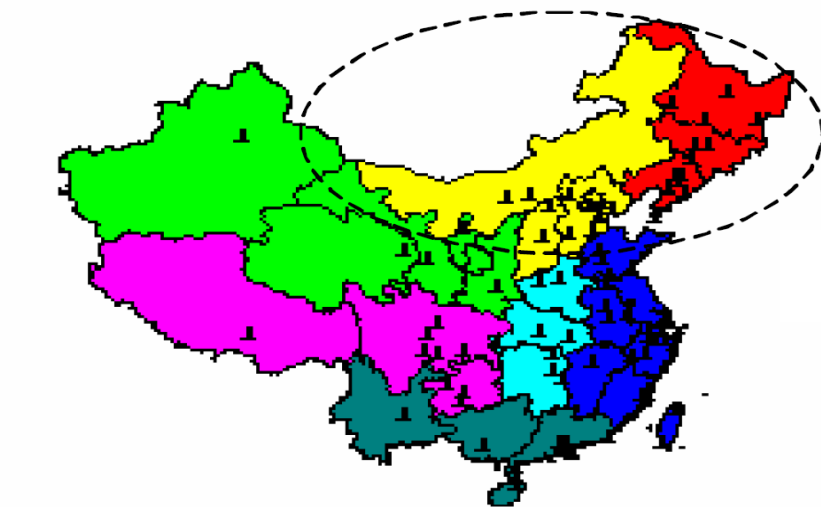

Figure 1 Location of Huabei plane in China

2.2 SEBS

The spatial distribution of water can be monitored with the help of remote sensing techniques. Satellite images are one of the very few sources to provide instantaneous information over large continental areas. Alterra has developed the Surface Energy Balance System (SEBS). This tool calculates maps of the surface energy balance parameters from the satellite images, which indicates how much water stress crops are experiencing at a particular instant in time.

2.2.1 NOAA/AVHRR evaporative fraction calculation

Before SEBS-NOAA (China_Drought version, Su et al, 2003) has been run on NOAA/AVHRR data in 2000, the model code has been checked carefully according to the theoretical formula of SEBS (Su, 2002) and several errors have been corrected. The code modifications are listed in the followings with the codes sections.

After the model code checking for the SEBS-NOAA China_Drought version, the model has been run with the NOAA/AVHRR image data as well as ground meteorological observations.

METEOLOGICAL DATA
The daily meteorological data in year of 2000 have been collected and its elements include Station number, Station longitude, Station Latitude, Station altitude, Surface visibility, Wind speed, wind direction, ambient air temperature, wet-bulb temperature and surface temperature.

NOAA/AVHRR
Totally 192 NOAA/AVHRR images have been collected (Done by Jin Xiaomei) with the total size of 2.19 GB. The data distribution among months in 2000 is listed in Table 1.

Table 1 Data distribution among months in 2000

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
File	19	17	13	13	16	15	15	17	19	16	17	15
Size	228	206	156	162	194	180	176	196	218	158	195	172

The details in time distribution of the NOAA/AVHRR data can be find in the Appendix 1.

Among 192 NOAA/AVHRR images, 53 NOAA/AVHRR image data have been processed and their corresponding evaporation fractions also have been calculated by SEBS. Some of the calculation results are listed in Figure 2-2.

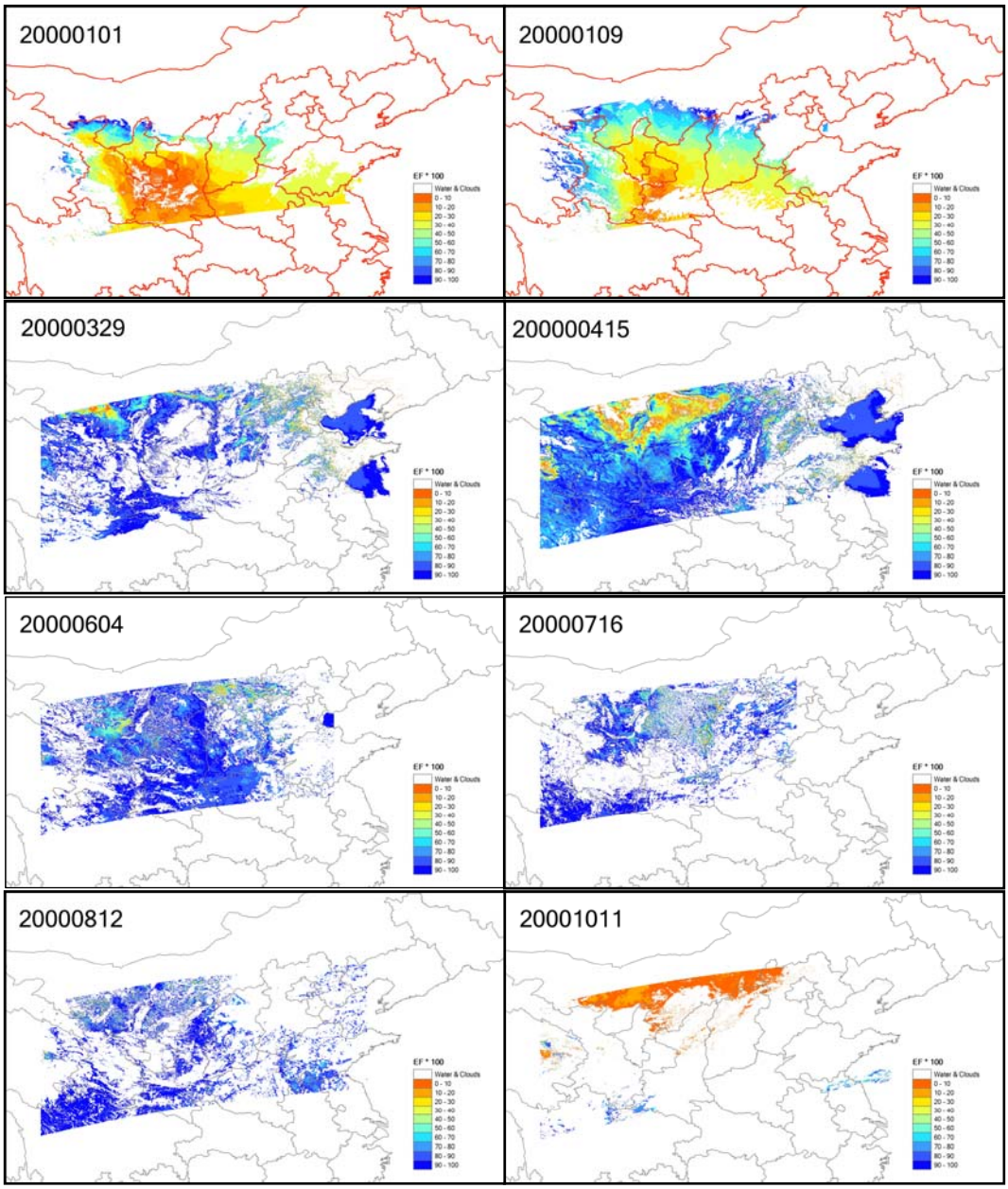

Figure 2-2 Evaporation Fractions calculated from SEBS

2.2.2 HANTS time series analysis

After having the 53 days' evaporative fraction results, a time series analysis has been performed to generate the whole year's time series evaporation fraction. The Harmonic Analysis of Numerical Time Series (HANTS) algorithm is used to perform the time series analysis. It is based on Fourier components, which reflect the start, length and magnitude of the time series behaviour during the year. This algorithm considers only the most significant frequencies expected to be present in the time profiles, and applies a least squares curve fitting procedure based on harmonic components (sines and cosines). For each frequency the amplitude and phase of the cosine function is determined during an iterative procedure. Input data points, which have a large positive or negative deviation from the current curve (like cloudy and missing pixels), are removed by assigning a weight of zero to them. After recalculation of the coefficients on the basis of the remaining points, the procedure is repeated until the maximum error is acceptable or the number of remaining points has become too small. For a detailed description of the HANTS algorithm one is referred to Verhoef (1996) and Roerink et al. (1999).

The parameters value set for HANTS' running is listed below:

- Number Of Frequencies = 4; the selected frequencies were the zero frequency (average) and the frequencies with time periods of 1 year and six months and three months. So the output comprises 7 Fourier coefficients (4 amplitudes and 7 phases).
- Suppression Flag = Low; this flag indicates that low values (outliers) should be rejected during curve fitting.
- Invalid Data Rejection Threshold = +100; this means that evaporative fraction values higher than 100 are rejected (the evaporation fraction has been multiplied 100).
- Fit Error Tolerance = 80 evaporative fraction units; the absolute error in negative direction of the remaining observations should be smaller than 80 evaporative fraction units with respect to the currently fitted curve.
- Degree of OverDeterminedness = 12; together with the minimum of 9 observations this gives that each fitted curve is based on a minimum of 21 observations in time, which is almost half of all data points.

Some of the HANTS derived images are listed in Figure 2-3.

After having the time series evaporation fractions by using HANTS, a movie MPEG file has been generated by using ENVI. The Evaporation faction variability in time and space fits the climate characteristics in Northern China Plain from the first impression of the motivation show.

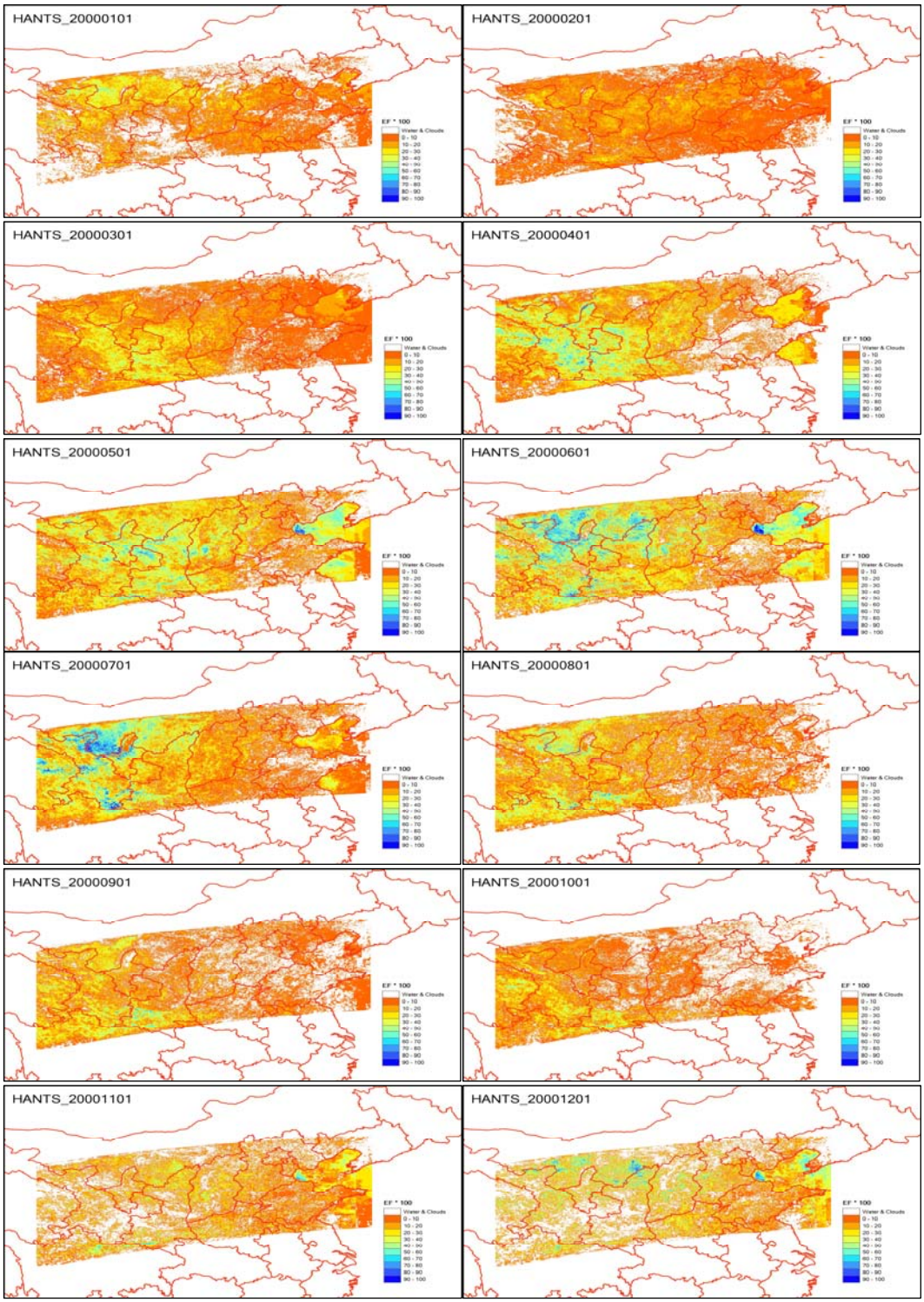

Figure 2-3 The HANTS evaporation fraction simulation results for the first day in each month

2.2.3 MODIS evaporative fraction calcultion

The MODIS instrument provides high radiometric sensitivity (12 bit) in 36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm, covering the wavelength range of NOAA/AVHRR with finer division in spectrum. The overpass time is around 11:00 AM local time.

The purpose for developing SEBS-MODIS is to use the MODIS data and its products as the inputs for SEBS. The MODIS 1B data (HDF-EOS format) is different from the NOAA/AVHRR 1B data (KLM 1B format) and The SEBS-NOAA can not use the MODIS data directly as its input.

Some results from SEBS can be replaced by the corresponding MODIS products published by DAAC (http://daac.gsfc.nasa.gov/), so the SEBS-NOAA has to been cut down and reconstructed to take the MODIS data products as inputs. The MODIS data products used by SEBS are MOD[03], MOD[09] and MOD[11A1], which provide the information of geo-location, reflectance, temperature and so on.

The following data have been collected and used for the SEBS-MODIS calculations.

MODIS data
The MODIS data products can be downloaded fro the EOS DATA GATEWAY (http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/). Till now, 9 days' MODIS data products (0401, 0402, 0403, 0406, 0411, 0412, 0417, 0421 and 0519) have been downloaded from the EOS DATA GATEWAY. The downloaded MODIS data products includes MOD03, MOD09 and MOD11A1, which can provide information of longitude, latitude, sunzenith, reflectance band1 and band2) and temperature for taking as the inputs of SEBS-MODIS.

Meteorological observations
The ground meteorological observations have been collected from National Meteorological Center, China. Since the over pass time of the MODIS is about 11:00 AM in Local time, then the meteorological data has been interpolated linearly from the two times' observations at 08:00 and 14:00 in local time.

Field observations
The 2001 measurements were conducted at the wheat field of Shunyi county, Beijing suburbs, China (40°12'N, 116°34'E). The site was relatively wide with about 700m length and 400m width. The range of LAI was 1.1-2.2 from 13 to 21 April.

The instruments of BREB system included one net radiometer, (manufactured by Jinzhou 322 institute, China); two soil heat plates (developed by China Agricultural University); and Bowen Ratio measuring instrument with sensors-position automatic exchange mechanism (developed by IGSNRR CAS). Air humidity was calculated relying on the dry-bulb and wet-bulb temperatures. Due to the Use of sensors-position auto-exchange technique, there is not systematic bias. The sensors of temperature is made of platinum, the precision is 0.03 ℃ and 0.05 ℃ in laboratory

and in field, respectively. The heights of temperature sensors were 0.6m and 1.6m above the ground, respectively. Two soil heat flux plates was buried at about 1 cm below the ground (one was under wheat row and another was under between rows), the net radiometer was mounted at 2m high over the ground. All data were collected by a data-logger (Data taker, DT100, Australia). The sampling frequency was 15 seconds, the interval of exchanging sensors-position and exporting the averages was 5 minutes.

The EC system consisted of a 3-D ultrasonic anemometer (model DA600, KAIJO Co., Japan), CO2/H2O analyzer was Li-7500, LI-COR Co., USA. They were used for quick measuring vertical wind speed, temperature and humidity, respectively. The system was installed near the BREB observation site. The height of sensors is about 2m above the ground. The data were collected by a high frequency data-logger (DASH-8, USA), the sampling frequency was 20Hz per channel. The averages were recorded every 10 minutes.

Surface infrared temperature sensor was installed at about 2m height, and its angle is about 45 degree, the data was continuously observed, like as radiation, type is BS-32T, 7-20 μm, View angle is 11 degree, it is made in Japan, OPTEX Co. Ltd. the data was recorded with DT100, the same data logger of BR system.

The measurements were made at a wheat field in Beijing shunyi county from 30/03/2001 to 24/04/2001, the following are the illustration of date contents.

A. Bowen ratio

date	date (MMDD, month-date)
Time	time (HHMM, hour-minute)
Th	dry bulb temperature in 1.6m high(C)
Tl	dry bulb temperature in 0.6m high(C)
Eh	vapor pressure in 1.6m high(mb or Hpa)
El	vapor pressure in 0.6m high(mb or Hpa)
Q	Global Radiation(w/m2)
Rk	reflected Radiation (w/m2)
Rn	net Radiation (w/m2)
G1	soil heat flux between wheat line (w/m2)
G2	soil heat flux under wheat (w/m2)
Rn-G	Rn-(G1+G2)/2, (w/m2)
H	sensible heat flux, (w/m2)
LE	latent heat flux, (w/m2)
Br	Bowen Ratio (unitless)
Ts	surface temperature of wheat field (C)

B. Eddy correlation

The sonic instrument was installed at 2m high , Type: DA600, KAIJO Co., Japan; CO2/H2O analyzer: Li-7500, LI-COR, USA, sampling frequency: 20 Hz/channel.

Date	date (MMDD, month-date)
Time	time (HHMM , hour-minute)
Tm	10min mean temperature (C)
Qm	10 min mean absolute humidity (g/m3)
Um	10 min mean wind speed (m/s)
Co2m	(mg/m3)
H_ed	sensible heat flux(w/m2)
LE_ed	latent heat flux(w/m2)
F_co2	CO2 flux(mg/s.m2)
Co2ppm	10 min mean co2 concentration (ppm)
U*	friction wind speed (m/s)

Measuring time is the beginning time, because of the accumulative time errors of eddy data, the eddy-data time may be 0-5 minutes error.

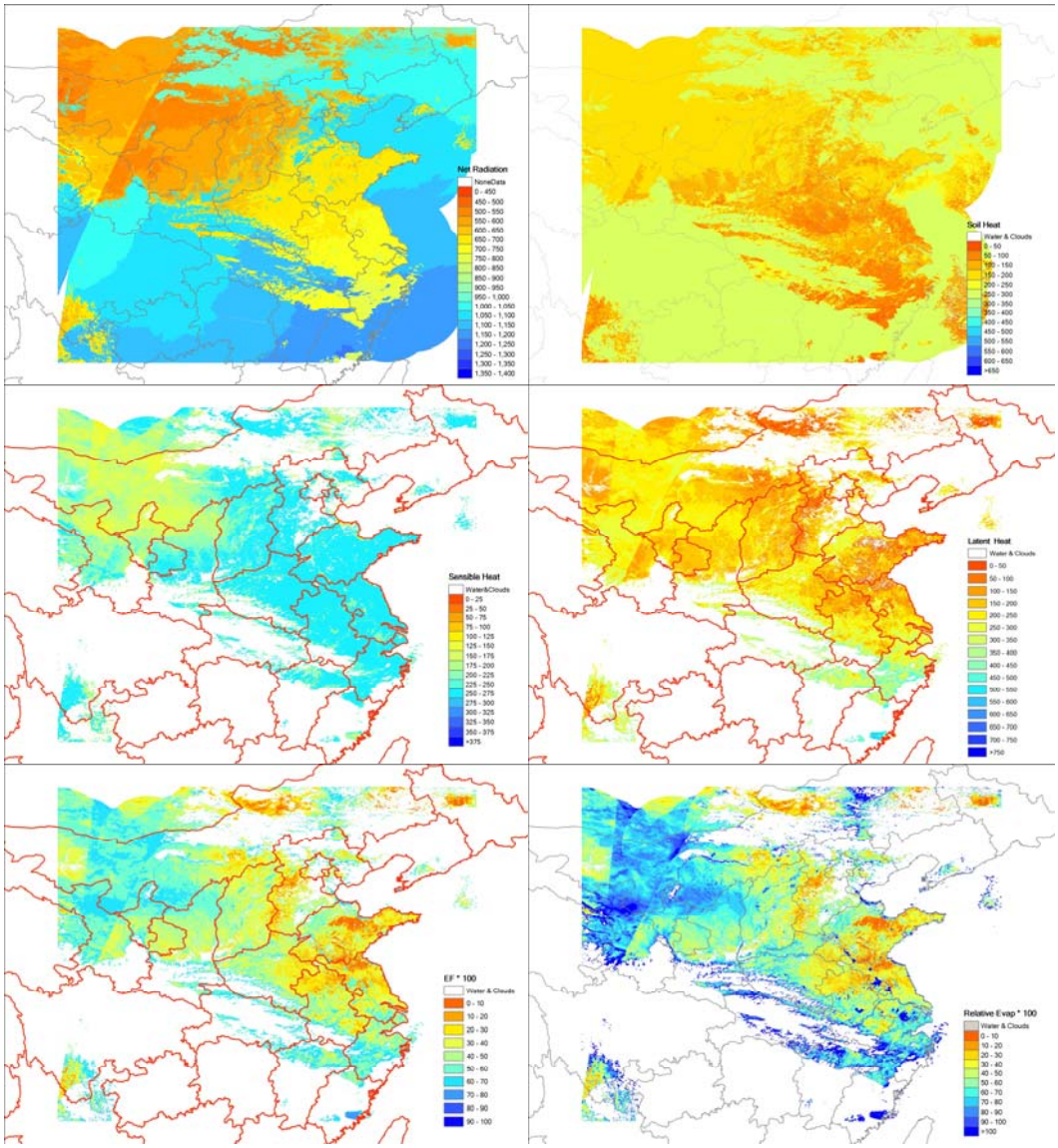

Figure 2-4 Evaporation Fraction calculations on MODIS data of Day 91, 2001

Results

The 9-days MODIS data products have been processed and inputted into SEBS-MODIS. As an example, the results for the Evaporation Fraction calculation on MODIS data of day 91, 2001, are presented in Figure 2-4.

While comparing to the field observations, only 4 days' calculation results are available for comparing. The other days are missing/unavailable of the temperature data and hence have no available calculation results for comparing. Although only 4-days calculation results are not extensive for drawing firm conclusions, the comparing results (Figure 2-5, Figure 2-6, Figure 2-6, Figure 2-7 and Figure 2-8) show that the net radiation has been overestimated as well as the latent heat fluxes. The soil heat fluxes and the sensible heat fluxes calculation results seem much better.

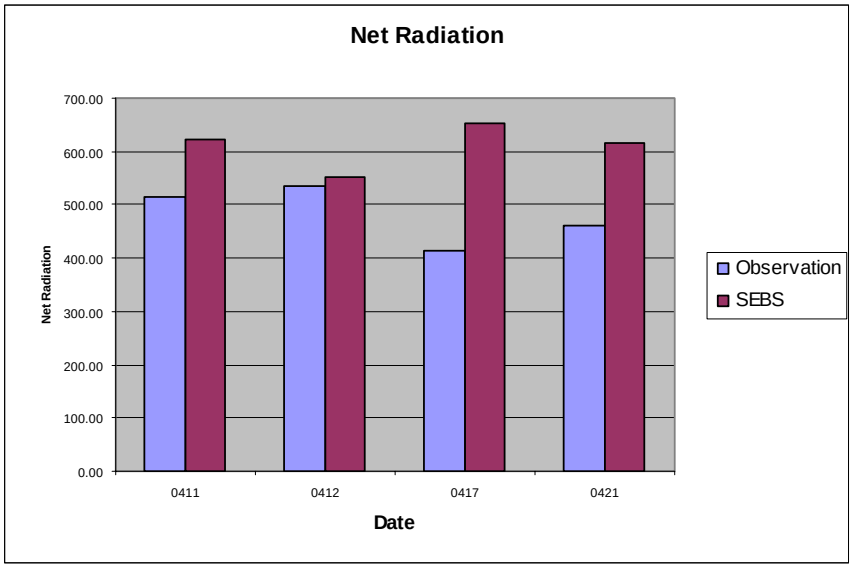

Figure 2-5 Net Radiation (observation vs calculation).

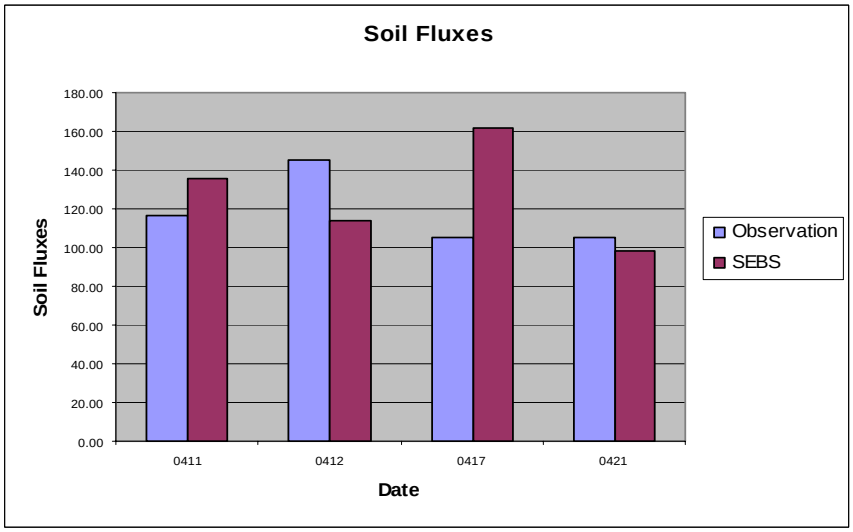

Figure 2-6 Soil Fluxes (Observation vs Calculations).

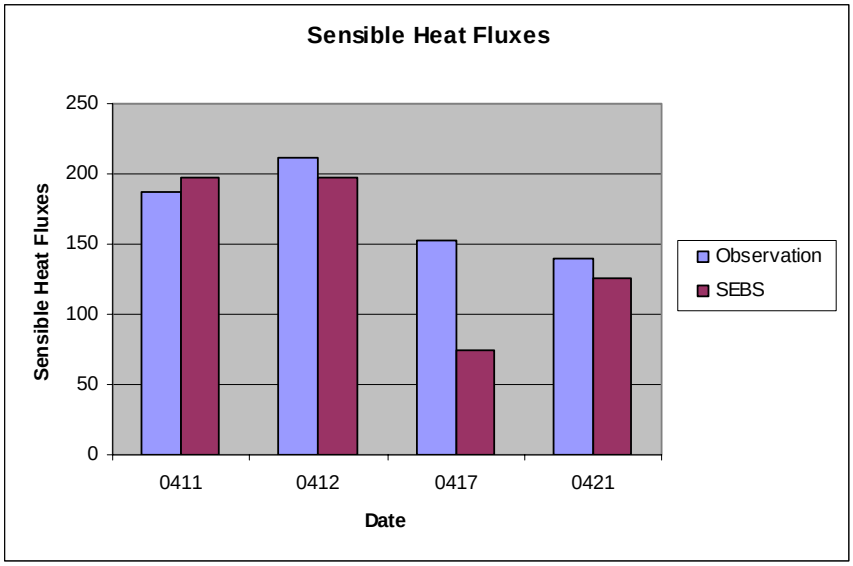

Figure 2-7 Sensible Heat Fluxes (observation vs calculation).

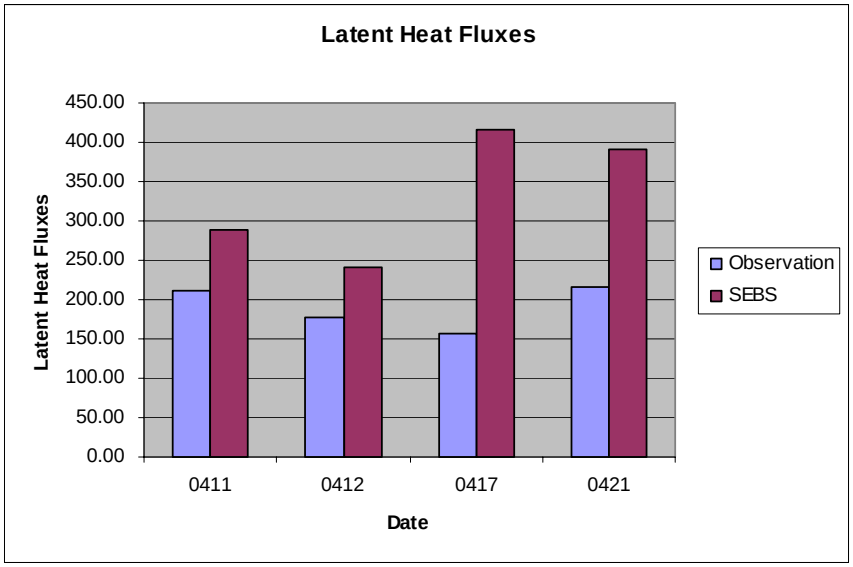

Figure 2-8 Latent Heat Fluxes (Observation vs Calculation).

2.3 Windscatterometer data reconstruction

The Windscatterometer (WSC) data provided by SarVision covers the period 01-01-1992 - 01-01-2001 with the ROI of 100°-125° E and 20°-50° N.

For each decade/month a file (ascii format) is included with the data for the entire ROI, and point coordinates are stored in an extra ascii file (lonlat.txt).

Since the data is stored in the original WSC analysis grid: the grid is defined such that the point spacing is approximately 28 km and the grid definition results in an irregular grid when transformed to geographic coordinates (please note that the resolution of the SWC is still 50 km).

Because of the grid definition is irregular and the ENVI input module can not be used to input the datasets into raster images format.

In order to input the datasets into raster image format, an arc/info AML routine has been developed to map each data points into its original map projection locations according to its corresponding latitude and longitude. Since the projection information for the original grids have not been attached to the datasets and also have not been specified by SarVision, who provided the datasets, an Albers projection with the following parameters has been assumed in this situation:

PROJECTION Albers
UNITS meters
DATUM WGS84
PARAMETERS
25 00 00.0
47 00 00.0
110 00 00.0
0 00 00.0
0
0

After having the projection-restored raster images, all the images further have been converted into geographic projections with the resolution of 0.03 degree.

After having the geographic projection information, all the soil water content (SWC) images for decade/month have been stacked (stacking.pro) into two ENVI image files for decadal and monthly SWC data respectively.

In Appendix 2 the program lists and directory structure of the NOAA/AVHRR, MODIS and WSC results are shown.