Estimates of Latent Heat and Sensible Heat Fluxes using Satellite data

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ABSTRACT

Latent and sensible heat fluxes over the global oceans are estimated using SSM/I (Special Sensor Microwave Imager) and AVHRR MCSST (Advanced Very High Resolution Radiometer Multi-Channel Sea Surface Temperature). The heat fluxes are computed from SSM/I wind speeds and surface humidity, the MCSST, and NCEP Reanalysis sea level pressures and 2-m temperatures from 1996 to 1997. The diabatic conditions bulk formula (Kondo, 1975) is used to compute the heat fluxes. To validate, the derived fluxes are compared to the measurements of 3 JMA buoys.

The wind speeds and surface humidity derived from SSM/I have accuracies of 1.37m/s and 1.7g/kg, respectively. The heat fluxes were estimated these factors and the standard error of the latent and sensible heat fluxes are 5.53 W/m^2 and 3.33 W/m^2. The latest El-Niño phenomenon started at the beginning of 1997 and this event was larger than any others. We compare the heat fluxes in 1997 with the fluxes in 1996 and investigate the spatial movement of meteorological factors as well as the heat fluxes associated with El-Niño appearance.

1. Introduction

The latent and sensible heat fluxes are important components for verifying coupled ocean-atmosphere models as well as driving ocean models. The heat fluxes data of higher spatial and temporal resolution can be provided using satellite measurements than ships, buoys and radiozondes.

The latent and sensible heat flux are estimated from bulk formulas which employ surface wind speed, air humidity, sea surface temperature and air temperature. To provide these factors on the global oceans, Goodberlet et al. (1989) have developed a new algorithm to retrieve the wind speed using SSM/I data. Wentz (1992), R. Atlas et. al (1996) and Kim et al. (1996) have suggested methods to estimate wind speed on the oceans. Liu et al. (1992), Schulz and Grassl (1993), Chou et al. (1995) and Schlüssel et al. (1995) have estimated the near-surface humidity from SSM/I measurements.

In this study, the first one is that we retrieve the above meteorological factors, and the latent and sensible heat fluxes on the sea surface. The accuracy of retrieved data are compared and assessed with those by other researchers. The second we investigate the variability of the fluxes around Korean Peninsular, and the factors and the fluxes on the tropical oceans associated with El-Niño appearance from 1996 to 1997.

2. Data

To retrieve wind speeds and surface humidity, we have used SSM/I grided brightness temperatures from January 1996 to December 1997. NOAA AVHRR Weekly MCSST, and 2-m air temperature and pressure of NCEP (National Centers for Environmental Prediction) have been used to estimate the latent and sensible heat fluxes on the global oceans. The weekly MCSST is spatially and temporally interpolated to the SSM/I measurement. The NCEP model provides the temperature data 4 times (0, 6, 12, 18 UTC) per day.

JMA Buoys data have been used to validate the retrieved satellite measurements for the same period as the above one. The measurement is 8 times (0, 3, 6, 9, 12, 18, 21 UTC) per day. The position of 3 JMA buoys are shown in Table 1.

Table 1. JMA Buoys used for the validation of the retrieval factors.

Possessor	Buoy Num.	Latitude (°N)	Longitude (°E)	Hight (m)
	21002	37.55	134.55	7.5
JMA	21004	29.00	135.00	7.5
	22001	28.10	126.20	7.5

3. Methodology

The latent E and sensible heat flux H are given by the bulk aerodynamic formulae:

$$E = -\rho L_v C_E U(Q_s - Q) \quad (1)$$

$$H = -\rho C_p C_H U(T_s - T) \quad (2)$$

where ρ is the density of the atmosphere, L_v is the latent heat of evaporation, C_p is the specific heat, and C_E and C_H are the bulk coefficients. U, T , and Q are the wind speed, the air temperature, and the specific humidity at the height of 10m. Q_s and T_s are the specific saturation humidity and the sea surface temperature.

The bulk coefficients were calculated by the diabatic conditions bulk formula of Kondo (1975). Q was retrieved using the equation of Schlüssel et al. (1995). The estimated standard error is 1.1 g/kg. U was estimated using the retrieval equation of Kim et al. (1996) who have slightly improved the algorithm of Goodberlet et al. (1989). The standard deviation of the retrieved global oceanic wind speed is 1.37 m/s under no rain condition with a small bias of 0.14 m/s and the root-mean square error is 2.01 m/s as seen in Fig. 1. The wind speed is at 19.5 m high. Thus, we have reduced the wind at 10 m high.

The air temperature T was calculated using a dry-adiabatic lapse rate of 2-m temperature of NCEP Reanalysis model and the sea level pressure P is also obtained from the model.

4. Results and Discussion

4. 1. Validation the retrieval data.

The retrieval humidity by Schlüssel et al. (1995) was compared with the JMA buoy measurements for the period from January to December 1997. The SSM/I data must be within a distance of 50 km and a time window of an half hour from the location and time of buoy measurement. The standard deviation and the bias are 1.72 g/kg and 0.35 g/kg. The larger error compared to the theoretical error is mostly caused by the time and location differences of the measurements (Schulz et al. 1997).

NCEP air temperatures which is simultaneous and the interpolated daily MCSST. The standard deviation of air temperature is 1.41℃ and the SST is 1.18℃.

We have estimated the latent and sensible heat fluxes using equation (1) and (2) from the retrieval components and then the estimated monthly heat fluxes were compared with the buoy measurements as shown in Fig 2. The plus values indicate that the sea releases to air and the minus ones mean the opposite. The accuracy of the monthly latent heat fluxes was the standard deviation of 5.53 W/m^2 and 5% of the average, and that of the sensible heat fluxes is 3.33 W/m^2 and 12%. The 27.78 W/m^2 bias of the monthly latent heat fluxes is in the range of 20-80 W/m^2 in the result by Chou et al. (1995). The 12% deviation fo the monthly sensible heat fluxes is a better result than 10 ± 37.6 W/m^2 of Konda et al.(1996).

4. 2. Variability of heat fluxes around Korean Peninsula

We have defined 5 regions around Korean Peninsula to investigate the variability of the heat fluxes according to the cold-air outbreak (Fig. 3a). The sea around Korea rapidly releases the large amount of heat fluxes in the cold-air outbreak episode due to the large different temperature and humidity between atmosphere and sea surface, and the strong wind speed. Fig. 4 shows the daily time series of the 5 regions of the latent plus sensible heat fluxes. The exact 0 value mean the missing day of SSM/I measurements. The heat fluxes on the 5 regions have the similar annual cycles and the large variations in the winter season. According to the cold-air outbreak episodes, the heat fluxes reach over -900 W/m^2 in the region 4 in Jan. of 1997.

4. 3. Variability of heat fluxes on the tropical oceans

To investigate the variation of the fluxes on the tropical oceans, we have chosen the Nino 1, 2, 3, 4, and WP (Warm-Pool)defined in this paper (Fig. 3b). The areas are in the range from the warm-pool of the east-south Asia to the coastal area of the southern American continent.

The anomaly data was derived from the monthly data for the period from January 1996 to December 1997. Fig. 5 shows the time series of the latent and sensible heat anomaly, SST, surface humidity, and surface wind speed. As seen the time series of SST Anomaly, the El-Niño event started at the beginning of 1997. The SST anomaly, surface humidity and wind speed in the eastern tropical Pacific Ocean have positive values and the latent and sensible heat fluxes are released more from the sea to atmosphere. This results are similar Liu et al. (1998) who have studied on El-Niño effect for the same period as this study.

5. Summary

The latent and sensible heat fluxes were retrieved from Satellite measurements that have higher spatial and temporal resolution by combining the retrieval wind speed, surface humidity SST, and NCEP model output.

The accuracy of surface wind speed is 1.37 m/s, the surface humidity is 1.72 g/kg under no rain condition from SSM/I measurements. The daily interpolated SST by Weekly MCSST algorithm have a accuracy of 1.18℃. The air temperature of NCEP Reanalysis have a standard error of 1.41℃. The standard deviations of the monthly latent and sensible heat fluxes are 5.53 W/m^2 and 3.33 W/m^2, and the biases are 27.78 W/m^2 and 23.11 W/m^2. These errors are due to the spatial and temporal different measurement time, and the number of each measurement in the same period.

To determine the influence of cold-air outbreak around Korean Peninsular, the daily time series of the heat fluxes in the 5 regions were analyzed. In the cold-air outbreak episode, the sea releases over -500 W/m^2 and -400 W/m^2 of the latent and sensible heat fluxes.

On El-Niño event, the anomalies of the SST, surface wind speed, and surface humidity are positive values, and the heat fluxes are more released from the sea to atmosphere on the eastern Pacific Ocean.

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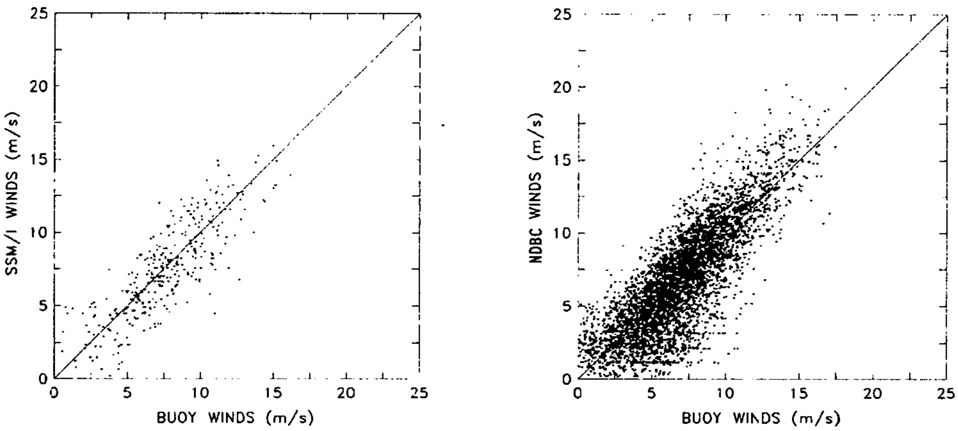


Fig. 1. Comparison between the near-surface wind speed derived from SSM/I measurements, and JMA and NDBC buoys.

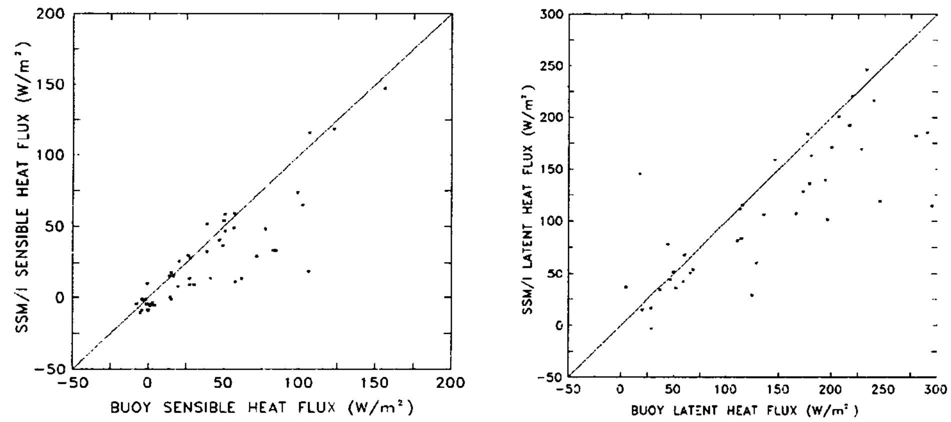
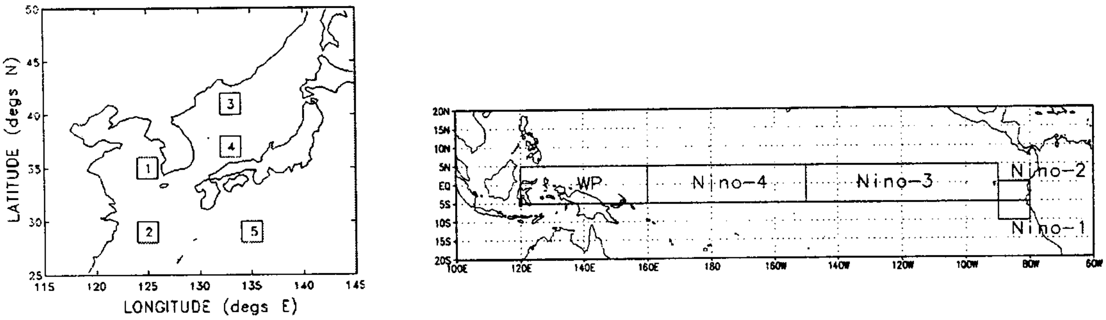


Fig. 2. Comparison between the latent and sensible heat fluxes derived derived from derived from Satellite measurements and JMA buoys.



(a) (b)

Fig. 3. Definition of 5 regions on seas around Korea Peninsular (a) and Positions of Nino 1, 2, 3, 4, and Warm-Pool area in the tropical ocean (b).

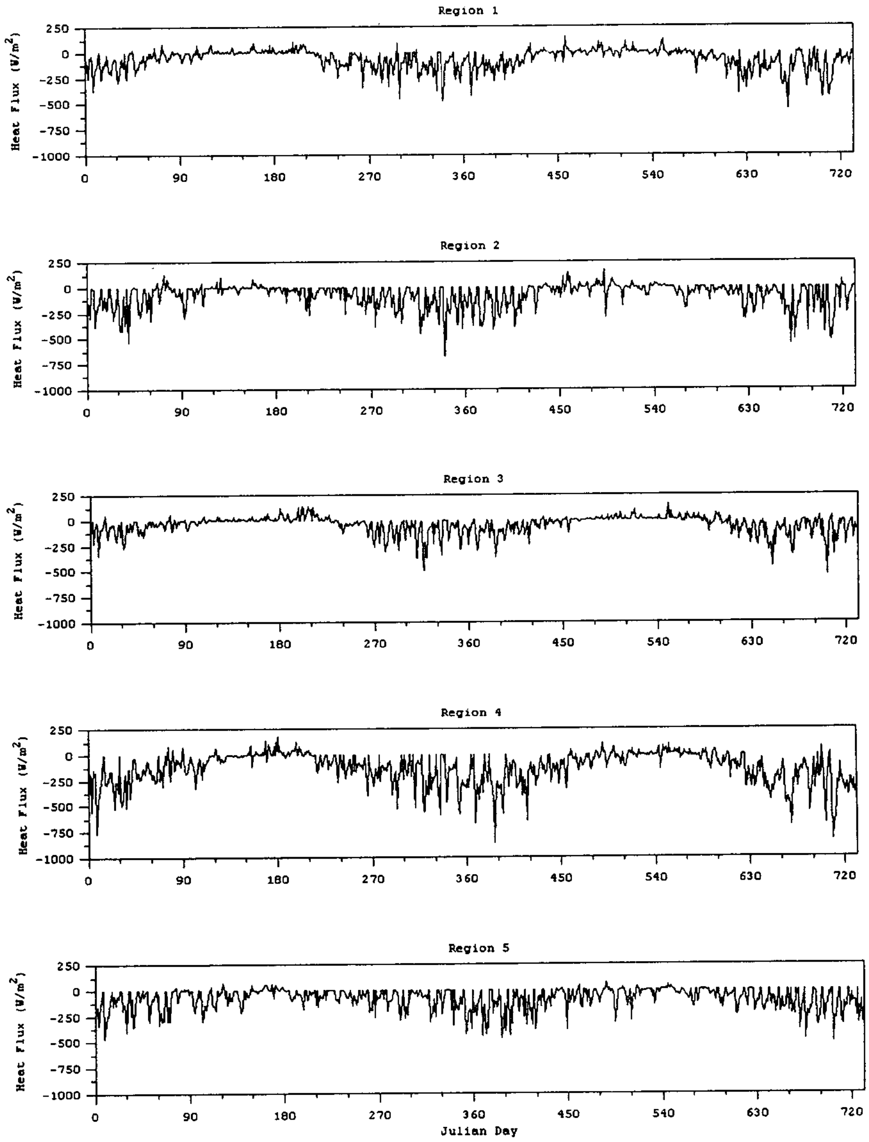


Fig. 4. Time series of the daily latent plus sensible heat fluxes on the 5 regions from Jan 1996 to Dec. 1997.

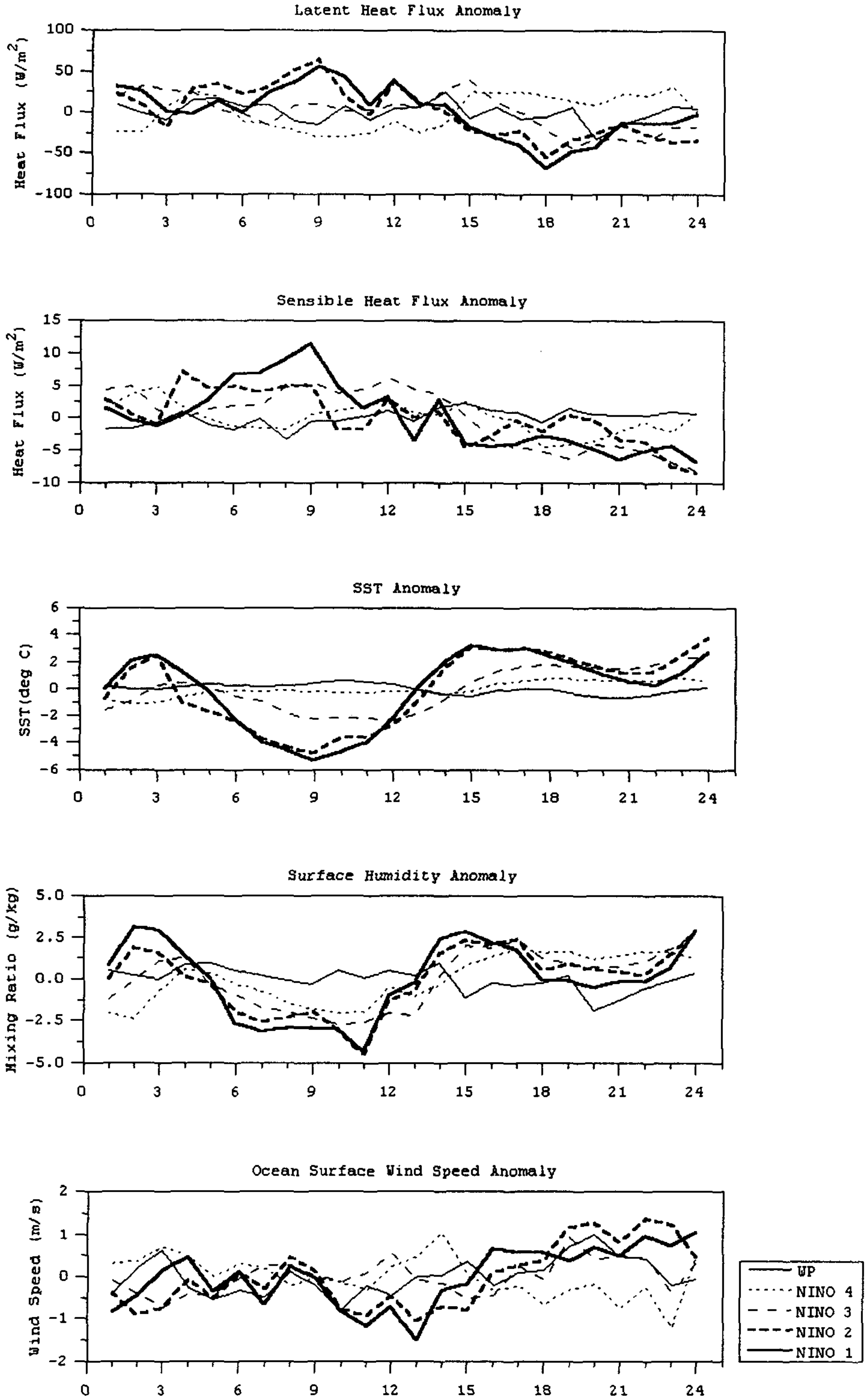


Fig. 5. Time series of the anomalous factors derived from satellite measurements