Latent Heat Flux over the Global Ocean

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ABSTRACT:

Though it was difficult to globally monitor latent heat flux over the ocean for many years, the situation is rapidly changing by the use of satellite data. Since a bulk formula is used to estimate turbulent heat flux using satellite data, we need wind speed, sea surface temperature and specific humidity data. However, it is not easy to accurately estimate specific humidity using satellite data. Now several algorithms for estimating specific humidity have been proposed and applied to construct latent heat flux data sets. Latent heat flux data sets derived from satellite data such as J-OFURO, HOAPS and GSSTF are available at present. Since the algorithm and used satellite data are not the same between them, the characteristics of each data set may be different. Therefore, it is important to clarify the difference between each data set and investigate the cause of the difference in latent heat flux estimates. In this paper we summarize the present state of the art with regard to the turbulent heat flux estimation by using satellite data. Also we present the comparison results of latent heat flux fields including not only satellite-derived flux fields but also analysis fields.

Key words: latent heat flux, satellite data, air-sea interaction, microwave sensor

1. Introduction

Heat transfer between ocean and atmosphere plays an important role in the global climate system. In particular latent heat flux is considered to be the most important component because it mainly determines variability of surface heat flux. Recently we can obtain global turbulent heat flux data using satellite and analysis data. However, since the characteristics of each data set depend on the data source and the algorithm, it is important to recognize the difference between each data set and clarify the cause of the difference.

Recently we constructed Japanese-Ocean Flux data sets with Use of Remote sensing Observations (J-OFURO) including turbulent heat fluxes, radiation heat fluxes and momentum flux etc. (Kubota et al., 2002). In this study we carry out the comparison of J-OFURO turbulent heat flux with other products and clarify the difference between each product.

2. Data

We compared following six global latent heat flux data sets. Hamburg Ocean Atmosphere Parameters Fluxes from Satellite Data (HOAPS), Goddard satellite-Based Surface Turbulent Fluxes (GSSTF), and J-OFURO are satellite-derived data sets. On the other hand, ECMWF and NCEP data are analysis data derived from a general atmospheric circulation model. Da Silva data set (da Silva et al., 1994) is based on in situ ocean observation data. Since original resolutions are different depending on each data set, we unified the spatial and temporal resolution to be 1 deg. and monthly in this study. The intercomparison is carried out for the period from 1992 to 1994 for all the datasets except for the da Silva data. The intercomparison period is from 1992 to 1993 for the da Silva data set.

3.Climatology

Figure 1 shows the mean latent heat flux as estimated by each product. The map shows that the largest values occur over the subtropical oceans around 20°, called the oceanic deserts. However, even in mid-latitudes we can find large values along the western boundary of the Pacific and Atlantic Oceans. These are caused by the effects of dry and cold monsoon and warm currents such as Kuroshio and Gulf Stream in winter (Masuzawa, 1952). On the other hand, latent heat flux is small over the equatorial oceans due to weak winds in the western part and relatively low SST caused by the effect of equatorial upwelling in the eastern part. Basically latent heat flux in the high-latitudes is considerably lower, less than 10 Wm^{-2}. Though both of HOAPS and J-OFURO are a satellite-derived products, the latent heat flux of J-OFURO is larger than that of HOAPS in the subtropics. On the other hand, it is interesting that the average difference between J OFURO and GSSTF is extremely small (Fig.2). J-OFURO underestimates in the equatorial regions and in the central part of the North Pacific compared with the ECMWF product. J-OFURO overestimates in the eastern part of the subtropics in the South Pacific and in the central part of the subtropics in the North Pacific compared with not only ECMWF but also NCEP1 and da Silva. The overall feature of the mean difference field between J-OFURO and ECMWF, NCEP1 and da Silva products is fairy common. However, the quantitative difference is not negligible. Though all of J-OFURO, Goddard and HOAPS are satellite-derived flux, the difference between J-OFURO and Goddard is relatively small, and the difference between J-OFURO and HOAPS is large, in particular in the subtropics. Analysis data such as ECMWF and NCEP data tend to overestimate in the equatorial region and underestimate mid- and high-latitudes compared with J-OFURO.

4. Variability

Figure 3 shows Root-Mean-Square (RMS) difference fields after removing the average difference. It is noted that the RMS difference is small compared with the average difference. In particular the RMS difference between J-OFURO and GSSTF is extremely small, less than 10 Wm^{-2} in most places. The RMS difference between J-OFURO, and other products except ECMWF is large, more than 50 Wm^{-2} in the tropical regions except around the equator. In particular, the difference between J-OFURO and the da Silva product is considerably large even in mid- and high-latitudes, though that is smaller than the average difference between them. On the other hand, the RMS difference between J-OFURO and ECMWF is large in the western equatorial Pacific and over the western boundary current such as Kuroshio and Gulf Stream.

Temporal cross correlation coefficients (CCC) are calculated at each grid point between the fields. The map of the cross correlation coefficient is given in Fig. 4. The CCC is extremely high, more than 0.96, between J-OFURO and GSSTF. On the other hand, the CCC between J-OFURO and HOAPS is high in the Northern Hemisphere and low in the Southern Hemisphere, though both of them are a satellite-derived product. The CCC between J-OFURO and da Silva is considerably smaller, less than 0.5 in most places, compared with other cases. The high CCC regions between J-OFURO and da Silva seem to correspond with regions where the observations are most abundant. This result suggests that the large variation in CCC in Fig. 4 is due to the lack of ship observations in the Southern Hemisphere and the da Silva product hardly reproduce time variability in the data sparse regions. Also the low CCC regions even between J-OFURO and NCEP1 or ECMWF are found over regions of data-sparse regions with low variability such as equatorial regions and high-latitudes in the Southern Hemisphere. This suggests that the effectiveness of NCEP1 and ECMWF may be limited to the Northern Hemisphere and the subtropics in the Southern Hemisphere.

5. Summary

Results from comparison of latent heat flux from J-OFURO with HOAPS, GSSTF, ECMWF NCEP1 and da Silva et al. (1994) have been presented. Time and space resolutions for data used are one month and 1 deg. by 1 deg., respectively. The comparison period is from 1992 to 1994 for all products, except for the da Silva product for which the period is during 1992 and 1993. The HOAPS and da Silva products are found to underestimate the latent heat flux in the tropical regions compared with the other products. The J-OFURO product generally gives large value of latent heat flux in the subtropics compared with other products except GSSTF. The features related to the da Silva product are considerably different from other products. For example, the mean difference filed between J-OFURO and da Silva products has a small-scale structure. The CCC between the products is extremely low in the Southern Hemisphere compared with the Northern Hemisphere where ocean observations are most abundant. These results suggest that the usefulness of the da Silva product in reproducing true variability may be limited to the Northern Hemisphere mid-latitudes and a few other regions. It should be noted that the differences in correlations between data-rich and data-poor regions are evident in correlations of ECMWF and NCEP1 with J-OFURO. This suggests that accuracy of the latent heat flux from Numerical Weather Prediction (NWP) product such as ECMWF and NCEP1 strongly depends on the density of assimilated data. Some of the comparisons may be affected by the difference in period between da Silva and other products. Since we, however, compare da Silva data with J-OFURO for the same period, the effects may be not so large compared with other factors.

References:

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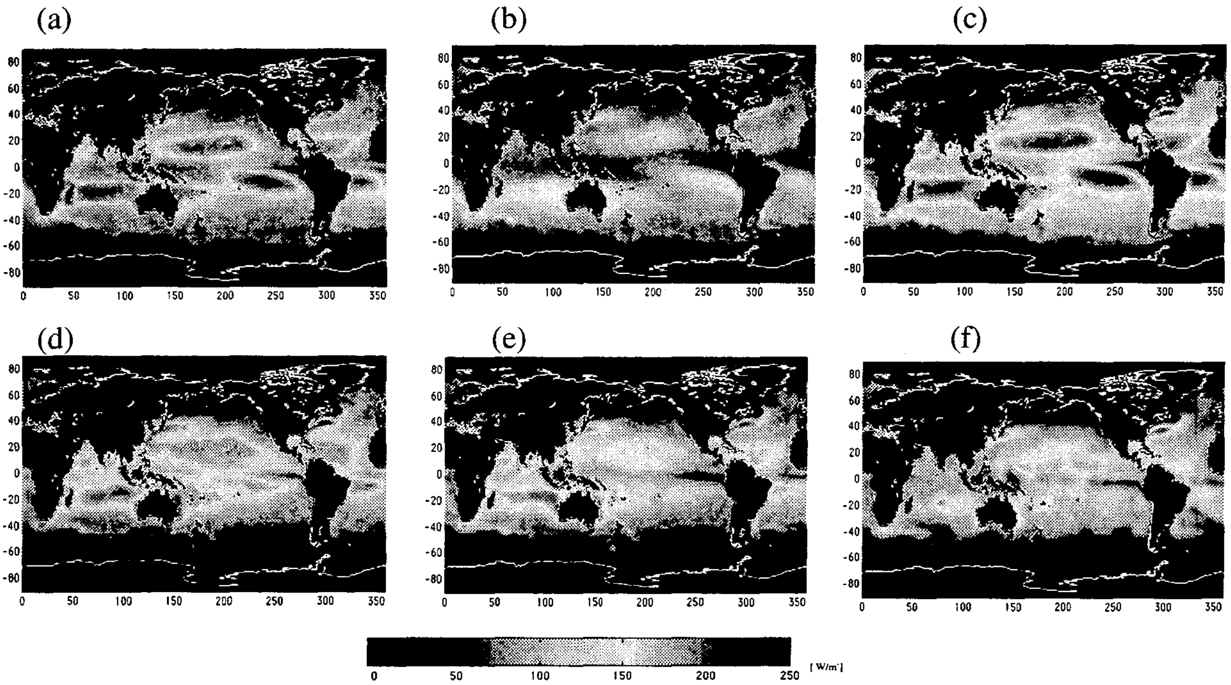

Figure 1. Average latent heat flux field. (a) J-OFURO, (b) HOAPS, (c)GSSTF, (d) ECMWF, (e) NCEP and (f) da Silva.

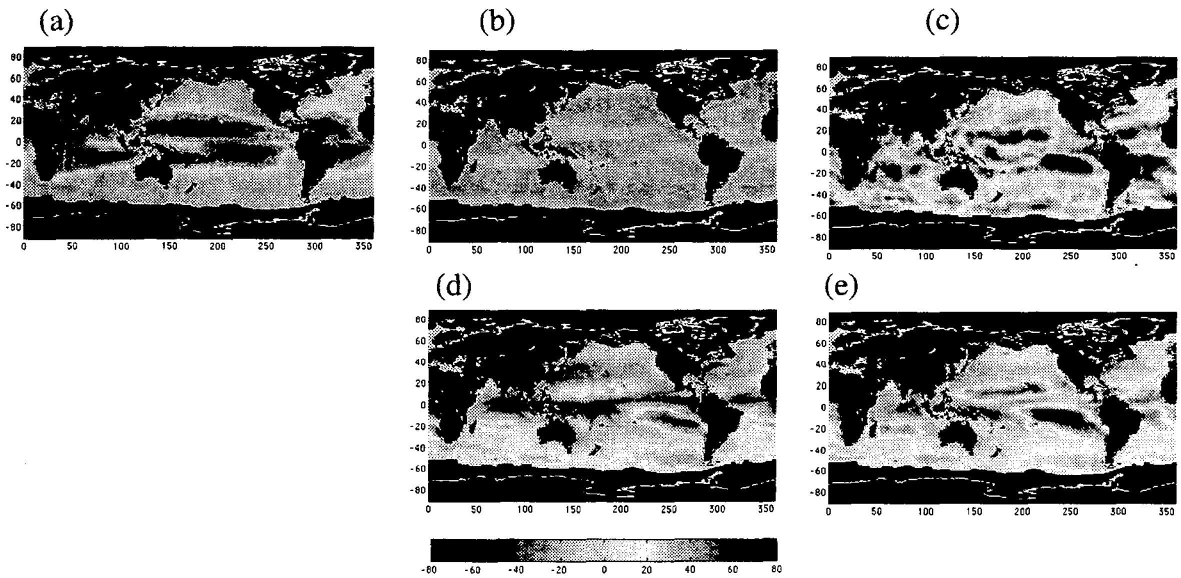

Figure 2. Average differences between J-OFURO and (a)HOAPS, (b)GSSTF, (c)ECMWF, (d)NCEP and (e) da Silva. Unit is W/m^2.

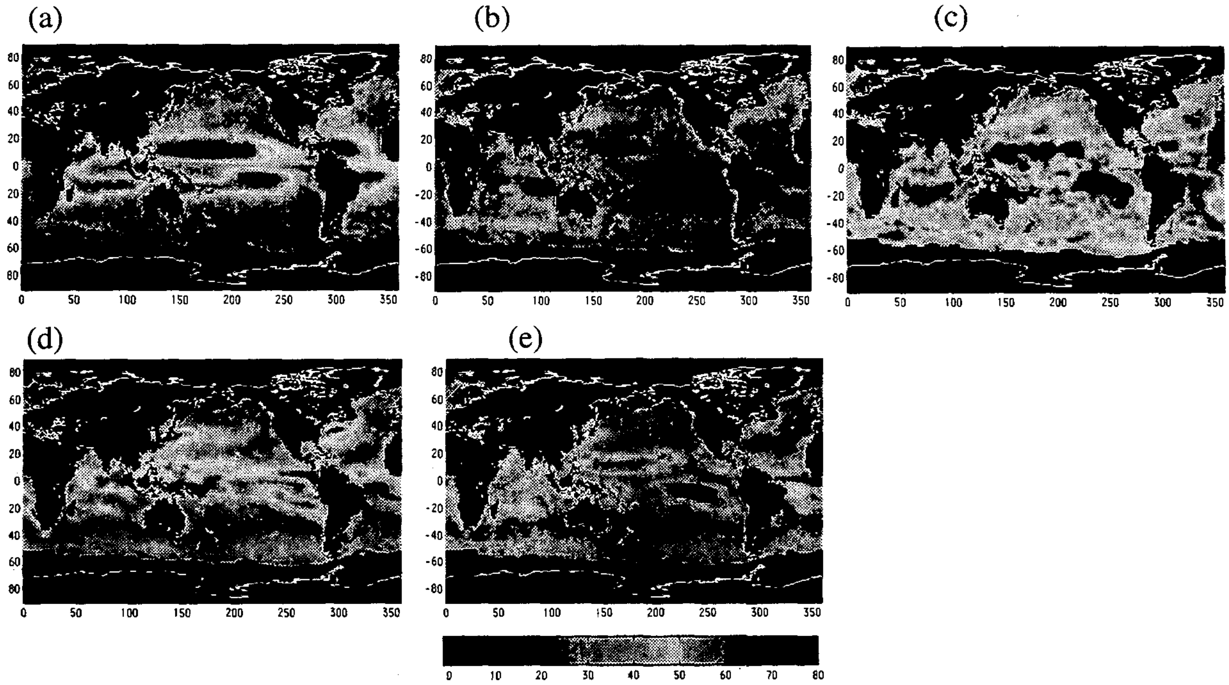

Figure 3.RMS differences between J-OFURO and (a)HOAPS, (b)GSSTF, (c)da Silva, (d)ECMWF and (e) NCEP. Unit is W/m^2.

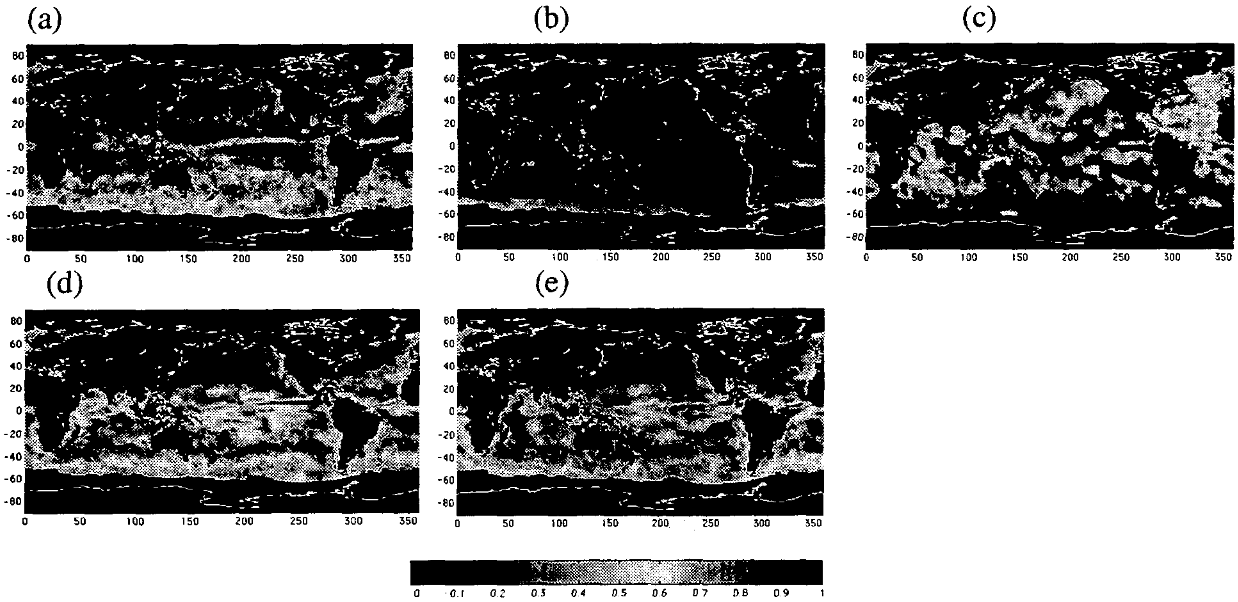

Figure 4. Correlation coefficients between J-OFURO and (a)HOAPS, (b)GSSTF, (c)da Silva, (d)ECMWF and (e) NCEP.