GLAS Global Analysis of Ocean Surface Wind and Wind Stress Using Seasat Scatterometer Winds

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Abstract

We present instantaneous and 10 day averaged fields of surface wind, wind stress, curl of the wind stress and Ekman transport divergence. These fields are derived from the GLAS four-dimensional analysis/forecast cycle, for the period 6-16 September 1978, using conventional data, VTPR soundings and subjectively dealiased SASS winds.

1. Introduction

The importance of determining surface fluxes of heat, moisture and momentum for the study of the ocean and its interaction with the atmosphere, especially in the tropics, cannot be overemphasized. Unfortunately these fluxes are not easily measured, and because of the lack of shipping routes throughout vast oceanic regions, even long term time means in these areas can only be determined by smoothing and extrapolation of values from better observed regions.

Surface wind stress is the single most important factor that determines the world ocean circulation. Estimations of wind stress have been made for certain regions by several authors (eg. Hellerman, 1967; Bunker, 1976; Hastenrath and Lamb, 1977, Wyrtki and Meyers, 1976; O'Brien and Goldenberg, 1983). Recently two papers have been published with global analyses of the wind stress over the oceans for each month of the year based on the same TDF-11 long data set. Hellerman and Rosenstein (1983) used all of the approximately 35 million ship wind observations available between 1870 and 1976 and computed monthly averaged wind stress in 2° by 2° boxes, with a surface drag coefficient C_D adapted from Bunker (1976), which depends both on wind speed and stability ($T_{air}-T_{sea}$). Han and Lee (1983) produced similar fields deriving them from the monthly averaged surface wind vector, assuming that the drag coefficient depends only on wind speed. They modeled the nonlinear dependence of the wind stress on wind speed by assuming a gaussian distribution of wind speeds and directions, with a standard deviation given by the observed (direction-independent) speed standard deviation. O'Brien and Goldenberg (1983) reanalized the 1961-1970 tropical Pacific data of Wyrtki and Meyer, and produced a long term as well as a year by year monthly wind stress atlas. In order to avoid the uncertainty associated the drag coefficient, they did not include either C_D or the surface air density in their definition of stress.

In this paper we discuss another method to compute day-by-day, gridded fields of surface wind and wind stress: the use of GLAS four-dimensional Analysis/Forecast System, which is similar to the systems used in several operational and research centers to produce atmospheric analyses. We present results for the 10 day period 6-16 September, 1978, during which we assimilated, in addition to conventional and VTPR sounding data, subjectively dealiased Seasat scatterometer surface winds produced by Woiceshyn, Peteherych, Wurtele and collaborators who kindly made it available to us. Although the GLAS Analysis/Forecast System produces other diagnostic fields, including surface fluxes of heat and moisture, in this paper we confine ourselves to the discussion of surface wind and stress. In Section 2 we briefly describe the GLAS system, the experiments performed and the data utilized. Section 3 contains an instantaneous comparison between our analysis and the hand analysis produced by Woiceshyn et al. Sections 4 and 5 are devoted to the 10 day average fields, and their comparison with other available mean fields, and Section 6 has a summary and conclusions.

2. Experiments with the GLAS Analysis/Forecast System

In the GLAS analysis/forecast 6 hour cycle, the GLAS Fourth Order General Circulation Model which has a complete set of subgrid scale physical parameterizations described in Kalnay et al., 1983, is used to produce a 6 hour forecast. This forecast serves as first guess for the next analysis of all available data within a window of ± 3 hours performed at 06, 12, 18, and 00 GMT. The analysis scheme is a successive correction method modified to account for data quality and data density (Baker, 1983). This system has been modified to allow for objective dealiasing and assimilation of Seasat scatterometer winds (SASS winds). Both the analysis and the forecasts are performed globally on a 4° latitude by 5° longitude grid.

Several experiments have been performed to study the impact of SASS wind data on weather prediction, denoted SASS, NOSASS, SASS-VTPR and NO SASS-VTPR, according to their use or lack of use of SASS winds and VTPR temperature soundings (Baker et al., 1984). These experiments made use of all conventional data, including ship winds, and the SASS winds were objectively dealiased within the analysis cycle.

In the present analysis we have made use of the SASS winds subjectively dealiased by Woiceshyn and collaborators in addition to other conventional and VTPR data. The results presented in this paper correspond to the analyzed surface wind (which coincides with the 6 hour forecast in data sparce regions) and the surface stress derived from the model's bulk formulation parameterization during the analysis cycle. Because the model is able to "transport information" from data rich to data sparce regions, the 6 hour forecast is a better estimation of the true instantaneous field than the first guess of an analysis which is not four-dimensional.

3. Comparison of synoptic (instantaneous) analyses

Fig. 3.1a and b present the GLAS surface wind streamline analysis for 00 GMT 15 September, 1978 and the corresponding subjective analysis performed by Peteherych et al. based on the use of subjectively dealiased SASS data from 13 GMT of 14 September to 01 GMT of 15 September, 1978. All the meteorological features described by Peteherych et al., are also present in the GLAS analysis. Among these note two typhoons off the coast of Japan, southwesterly monsoon flow on the coast of equatorial West Africa and the Indian subcontinent, the cyclones and anticyclones in the Northern and Southern Hemispheres, the strong westerlies that drive the Antarctic circumpolar Ocean current, the trade winds from the Northern and Southern Hemispheres meeting in the ITCZ at about 10°N, and others. In addition, a weak cyclone present at 45°N, 40°W, was detected in the GLAS analysis and not in the hand analysis because it is in a region where no SASS data was available due to the SEASAT orbital configuration.

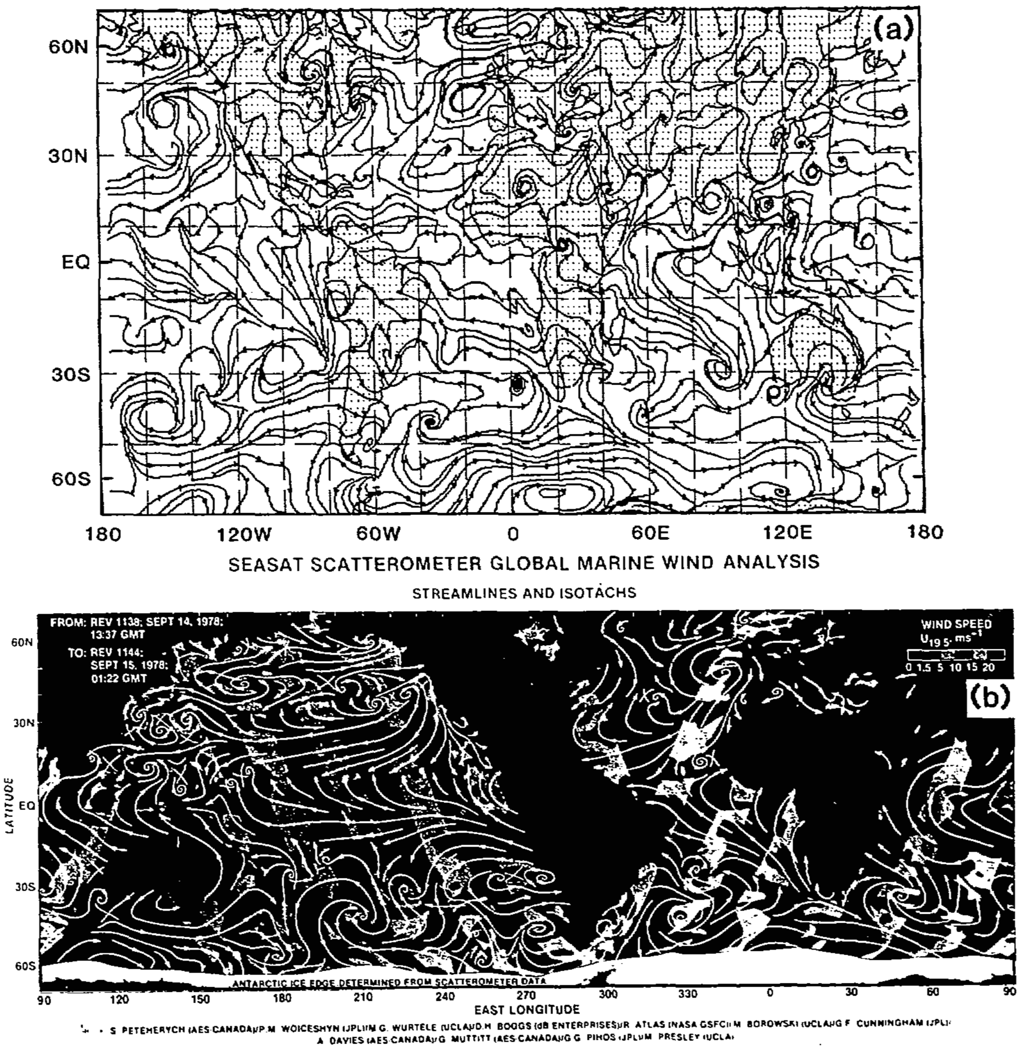


Fig. 3.1: a) Instantaneous surface wind streamlines for 15 September 1978, 00 GMT from the GLAS analysis. b) Hand analysis by Peteherych et al.

Fig. 3.2 presents the instantaneous wind stress field for the same date. The most notable feature is the intense stress associated with the enormous Southern Hemisphere cyclone pointed out by Peteherych et al, and centered at 32°S and 135°W.

4. Ten day averaged surface wind and wind stress fields

Although we do not yet have longer term averages, in this and the following section we present 10 day averaged fields corresponding to our analysis of 6-16 September 1978 and compare them to several available climatological fields.

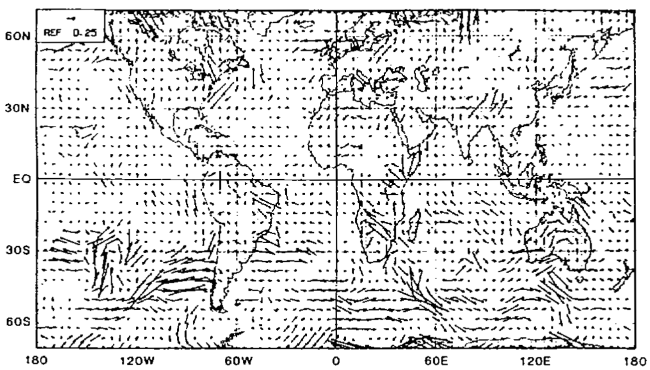


Fig. 3.2: Instantaneous surface stress field (N m^{-2}) for 15 September 1978, 00 GMT from the GLAS analysis.

Fig. 4.1a, b, c presents a comparison of the long term mean vector of surface winds in the GATE area during September adapted by Burpee and Reed (1981), and our GLAS analysis surface wind for the 10 day period 6-16 September 1978. There is very good agreement between these fields, with a col at about 10°N and 27°W. West of this col the trade winds converge into the ITCZ which is located at about 10°N. East of the col, the winds are towards the east, converging towards a broad cyclonic circulation located over the maximum surface temperature at about 20°N and 10°W. The cyclone center our analysis is displaced towards the Greenwich meridian. The mean (vector) wind speeds are also in reasonable agreement, with the larger values in the GLAS analysis probably due to the short averaging period.

In Fig. 4.2 a, b, we present the 10-day mean surface stress derived from the GLAS analysis cycle for September 6 to 16, 1978, using the subjectively dealiased SASS wind data. For comparison, we include the stress vector fields O'Brien and Goldenberg (1984). Our 10 day average generally agrees with these climatological fields. There is maximum negative zonal stress of more than .1 N m^{-2} west of the coast of both South and North America, the meridional stress is generally positive (towards the Northern Hemisphere) across the equatorial Pacific, except west of the dateline but weaker in our 10 day average than in climatology. The zonal stress is negative (towards the west) in all the tropical Pacific except for regions of weak easterly stress in the Northern Hemisphere near Indonesia and off the coast of Central America.

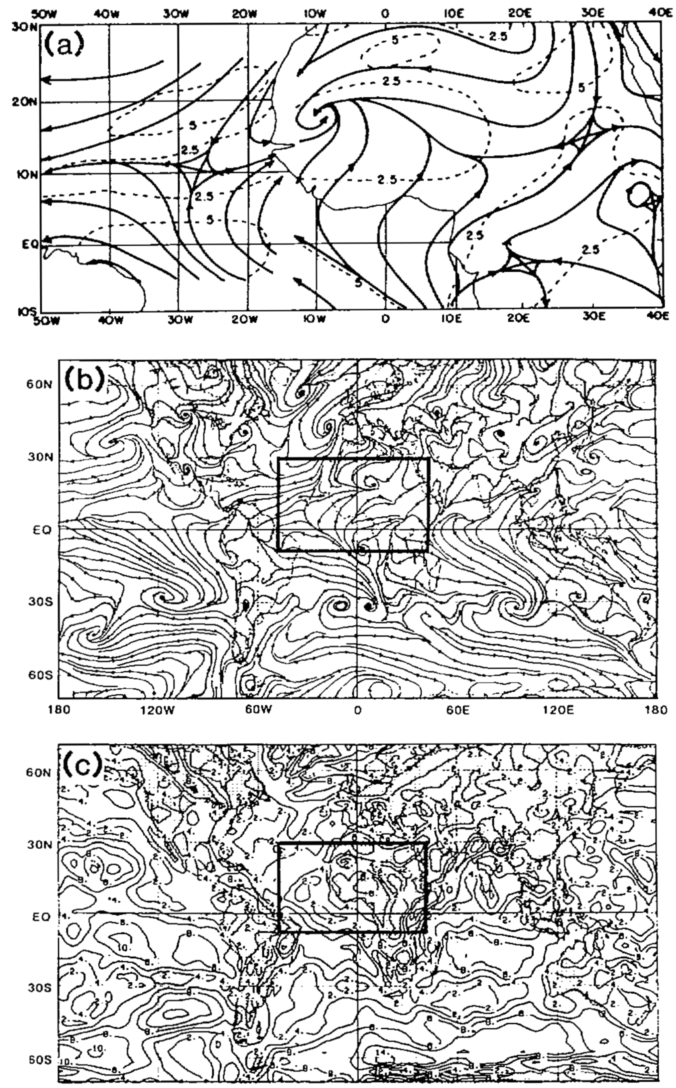
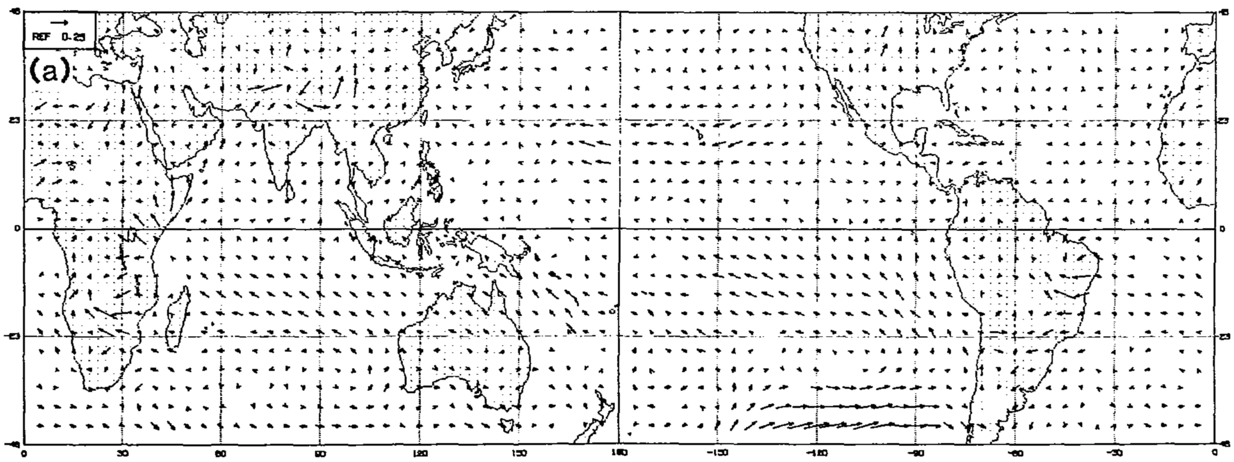


Fig. 4.1: a) Long-term mean streamline and isotach pattern for September near the surface in the GATE area. Burpee and Reed (1981). b) Mean surface streamlines for the period 6-16 September 1978 for the GLAS analysis with the GATE area outlined. c) Same as b but mean wind isotachs (m sec^{-1}).

In Fig. 4.3 a, b we compare the global mean surface wind speed from our 10 day analysis with the climatological surface wind speed from Esbensen and Kushnir (1982). Again, the agreement is generally good, if the differences in averaging periods is taken into account. Note that both of these maps are based on the averaging of the wind speed. The result of computing the speed of the mean wind vector is quite different (Fig. 4.1 a). The standard deviations of the vector wind and of the wind speed are correspondingly different (Fig. 4.4 a, b), with the second one smaller and much more uniform throughout the globe.



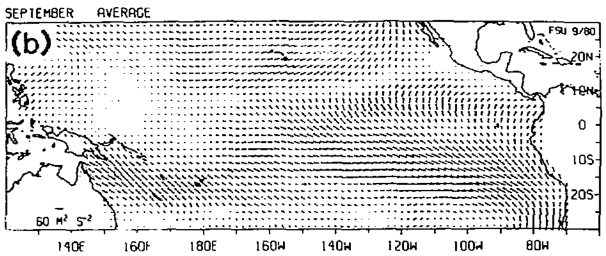


Fig. 4.2: a) 10 day mean surface stress from the GLAS analysis. b) 1961-1970 September surface stress vectors (O'Brien and Goldenberg, 1983).

5. 10 day average wind stress curl and Ekman transport divergence

Fig. 5.1 presents the curl of the 10 day average curl of the wind stress from an analysis and the climatological (1961-1970) wind stress curl for the Pacific from O'Brien and Goldenberg (1983). Even for only 10 day averages, the average curl of the wind stress shows the large scale structure of the mean flow, and agree qualitatively with the zonal bands of positive and negative stress pointed out by Hellerman and Rosenstein (1983), especially in the central and eastern Pacific, where the circulation is less affected by the changes in season. In both results the curl of the wind stress has maxima of about 1-2 x 10^{-7} N m^{-3} (or 10-20 x 10^{-9} dyne cm^{-3}). There is also qualitative agreement with the field derived by O'Brien and Goldenberg.

Fig. 5.2a and b present divergence of the Ekman transport, defined as

$$\nabla \cdot v_E = \frac{1}{af} \left(\frac{1}{\cos\phi} \frac{\partial \tau^\phi}{\partial \lambda} - \frac{\partial \tau^\lambda}{\partial \phi} + \frac{\tau^\lambda}{\sin\phi \cos\phi} \right) .$$

There is qualitative agreement between Hellerman and Rosenstein's (1983) fields and ours although, unlike Hellerman and Rosenstein, we did not distinguish between land and ocean, or imposed the boundary conditions $\tau x = \tau y = 0$ at the ocean boundaries.

6. Summary and discussion

We have presented instantaneous and 10 day averaged gridded fields of surface wind and wind stress derived from the GLAS Analysis/Forecast cycle for 6-16 September 1978, using subjectively dealiased SASS winds. The results so far are encouraging, showing genally good agreement with the instantaneous hand analysis, and consistency with climatological fields. We plan to analyze the 3 months of SASS data, as well as the FGGE year.

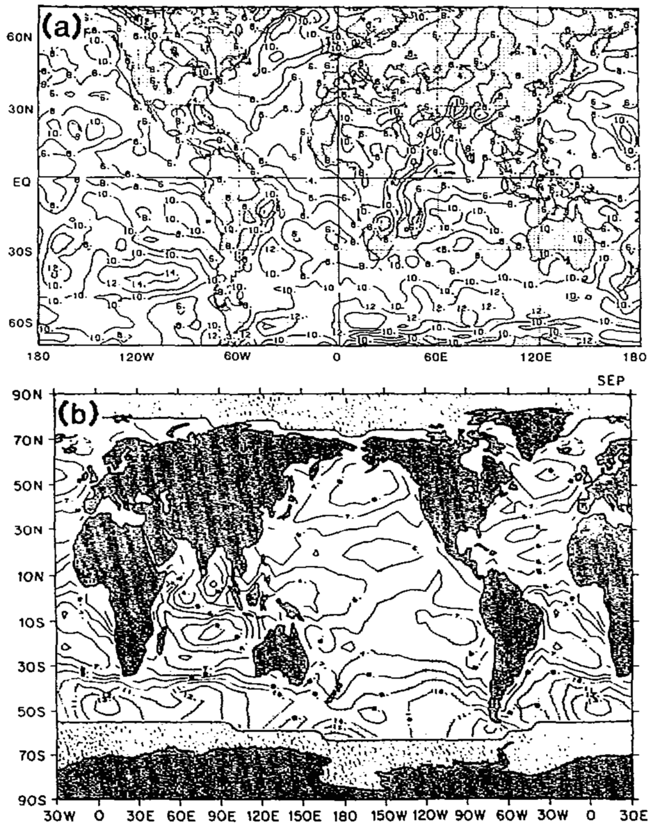


Fig. 4.3: a) 10 mean surface wind speed from GLAS analysis. b) Global mean surface wind speed from Esbensen and Kushnir (1982).

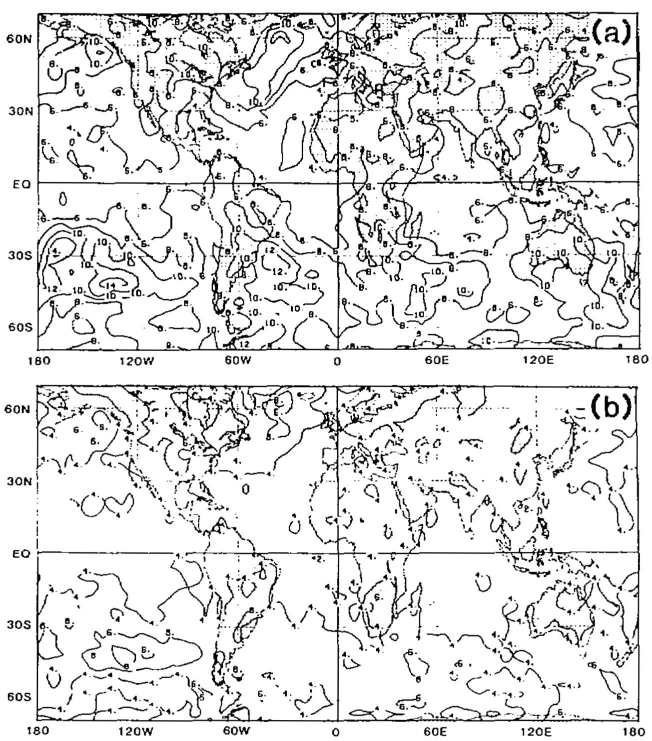


Fig. 4.4: a) Standard deviation of surface wind vector. b) Standard deviation of the surface wind speed.

Long term gridded analyses will facilitate the systematic study of the temporal and spatial scales in the wind field over the ocean (and land). They will allow computation of spectra without the need for further smoothing, which, as indicated by Willebrand (1978), can seriously distort time scales shorter than 10 days, characteristic of most of the extratropical atmospheric disturbances.

The characteristics of the surface fluxes of heat and moisture also diagnosed by the GLAS analysis will be discussed in a later study.

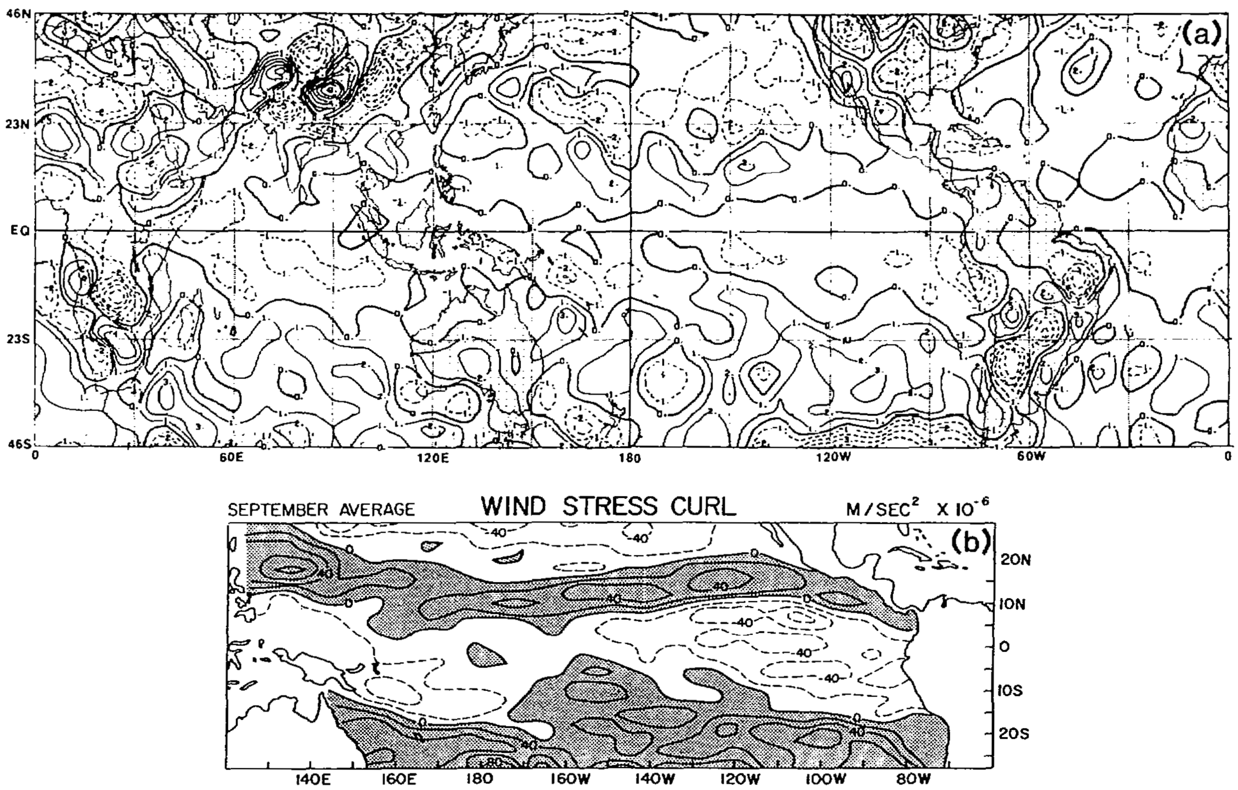


Fig. 5.1: a) Curl of 10 day mean surface wind stress from GLAS analysis. b) Curl of September surface stress (O'Brien and Goldenberg, 1983).

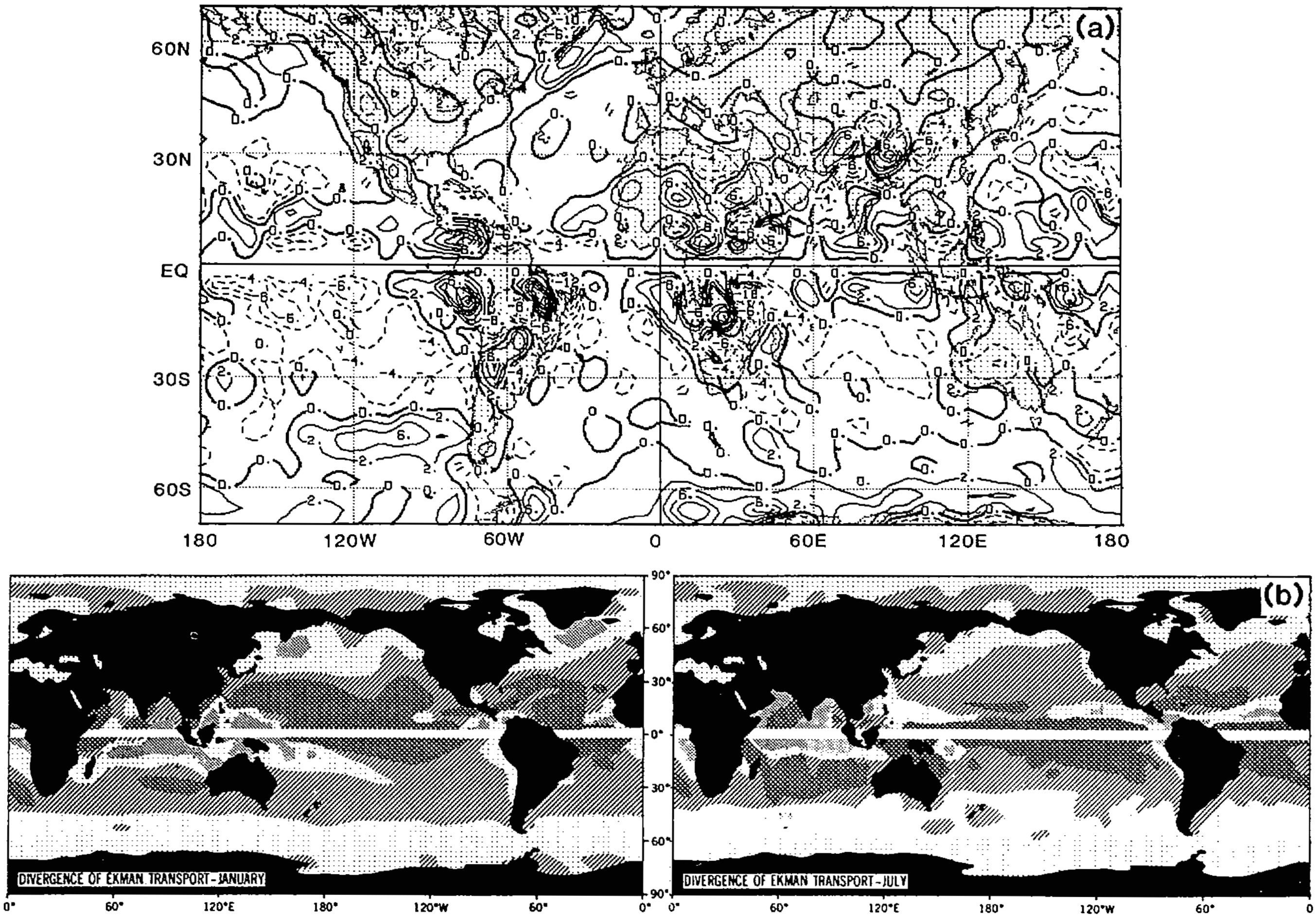


Fig. 5.2: a) 10 day average divergence of Ekman transport from GLAS analysis. b) Divergence of Ekman transport for January and July (Hellerman and Rosenstein, (1983).

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