TROPICAL CYCLONE INTENSITY FROM SCATTEROMETER WINDS

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1. Introduction

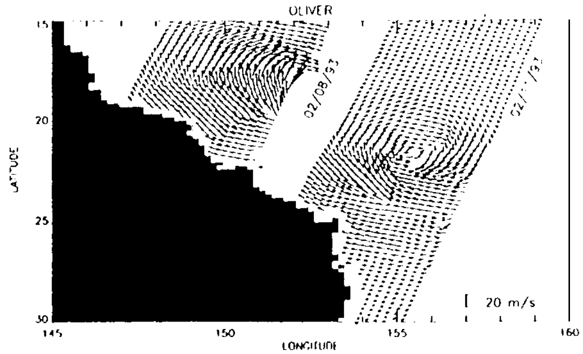
Tropical cyclones, devastating when accompanied by high winds, low pressure and heavy precipitation, are one of the most intense type of storms. They are smaller than extropical cyclones and have proven difficult for operational analyses (e. g., European Centre for Medium Range Weather Forcasting (ECMWF)) to resolve, ERS-1 scatterometer winds revealed an unprecedented level of detail in the circulation of tropical cyclone Oliver as it passed through the TOGA COARE area (Fig. 1) near the end of the Intensive Operation Period (IOP).

In this paper, wc demonstrate that accurate estimates of tropical cyclone intensity over data sparse ocean regions are made possible through a planetary boundary layer model that relates the pressure gradient to surface winds observed by the ERS- 1 scatterometer. This scatterometer wind data is used to estimate the surface pressure, which is one of the indicators of the intensity of a cyclone. pressure gradients arc derived from ERS-1 surface winds using a planetary boundary layer (PBL) model which is based on similarity theory and includes the effects of stratification, secondary flow and thermal wind. These pressure gradients are integrated with available observations to produce a surface pressure field for the region occupied by the tropical cyclone.

One of the difficulties in deriving surface pressure fields in the tropics is that the pressure field and the wind field are not in geostrophic balance. A gradient wind relationship that considers the curvature of the wind is applied. It is found that the effect of curvature on pressure. value.s can be more important than stability or secondary flow, which are crucial in deriving accurate surface pressure fields in mid-latitudes.

2. Data

The data used in this study are the ERS - 1 (First European Remote Sensing Satellite) scatterometer winds. The ERS-1 wind data were interpolated onto a twice-daily, 10 longitude by 1° latitude grids using a successive. correction method based on Bratseth (1986). At a particular time, an ECMWF field was used as a initial guess. ERS-1 data within a time of influnce (1.5 day) were used to correct wind vectors at grid points. The con tribution of an ERS -1 observation to the correction was weighted by its distance in space and time from the grid point.



Fig, 1. Surface wind fields in two ground tracks of the ERS-1 scatterometer, showing the evolution of the tropical cyclone Oliver. (after Liu et al., 1993)

3. Methodology

To obtain pressure fields, we use the two-layer PBL model based on similarity theory develpoed by Brown and Liu (1982) that relates the geostrophic wind vector to the surface wind vector, surface roughness, stratification, secondary flow and thermal wind. The model includes a surface layer and an outer layer,

For the surface layer,

$$U / u_* = 1 / k[\ln(z / z_o) - \psi(z / L)]$$

where U is surface wind, u_* is the surface wind stress, z is the height of wind speed measurement, z_o is the surface roughness length, *k is the* von kármán's constant, and ψ is determind empirically and depends on the Monin-Obukhov length, *L*. The effect of moisture fluctuations on buoyancy is included in *L*.

For the outer layer,

$$U = \cos\alpha + u_t\zeta + e^{-\zeta}[(\cos\zeta - \sin\zeta)\sin\alpha + v_t\sin\zeta] + V_2$$

$$V. -\sin\alpha + v_t\zeta + e^{-\zeta}[(\cos\zeta + \sin\zeta)\sin\alpha + v_t\sin\zeta] + V_2$$

where u, and v, arc thermal winds, ζ is z/L, U_2 and V_2

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are secondary flow, and a is the geostrophic departure angle.

To obtain u,, drag coefficients for momcmtum, heat and moisture have to be solved simultaneously through iteration. 'I'he moisture transfer coefficient in the surface layer is modified according to Bradley et al, (1991) based on Liu et al. (1979) and methods of appl ying satellite data (c. g. Liu et al., 1994) in the tropical oceans are being pursued.

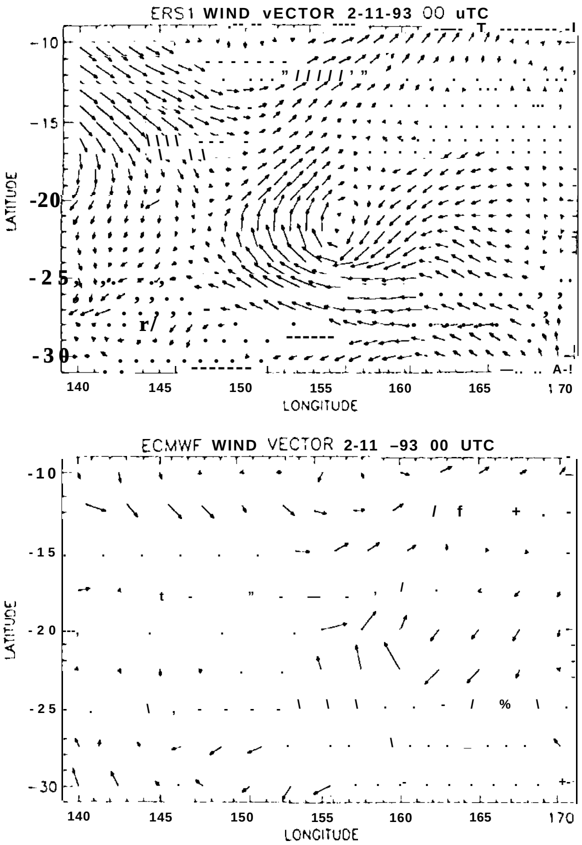

Fig. 2. Objectively analyzed ERS-1 wind field (top) and the corresponding ECMWF analysis (bottom) near tropical cyclone Oliver for Feb 11, 1993.

The scatterometer wind vectors along with ECMWF sca surface temperature, surface air temperature and humidity are used as inputs to obtain pressure gradients. A gradient wind balance is assumed to exist between these pressure gradients and the winds at the top of the boundary layer. Pressure values arc then integrated with available observations to produce a surface pressure field for the region occupied by the tropical cyclone. An inversion **method is used to minimize thc errors introduced** through the integration.

4. Results

On 11 Feb 1993 ERS-1 scatterometer winds have full coverage of tropical cyclone Oliver (Fig. 1). The interpolated scatterometer wind field and the corresponding ECMWF wind analysis (2.5° x 2.5° resolution) are shown in Fig. 2. There is a substantial discrepancy between the two fields in the location of the low center. The cyclone center is near 156°E, 22°S in the ERS-1 analyses, while ECMWF winds show it to be at 161°E, 20°S. The tropical cyclone exibits stronger intensity in the pressure field derived from scatterometer winds even when curvature effect is not considered and has a central pressure of 1014 mb compared to the 1016 mb in the ECMWF analyses (Fig. 3).

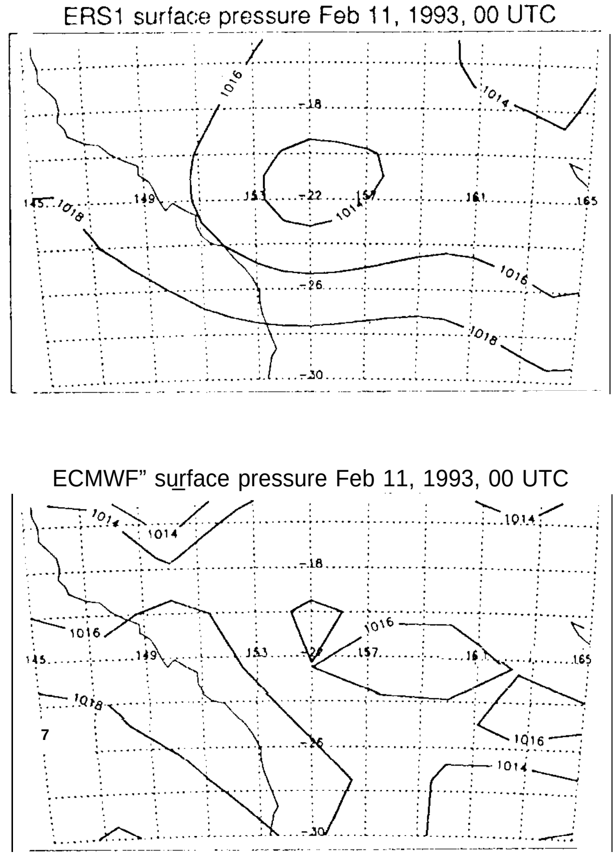

Fig. 3. Pressure fields with neutral stability derived from ERS-1 scatterometer wind (upper) and from the ECMWF sea level pressure analysis (lower) for Feb 11, 1993,

When other forcings arc included in the PBL model, the position and the magnitude of the central pressure derived from scatterometer winds are affected. In mid-latitudes, the effect of secondary flow and stability can be significant because the size of the cylones in those latitudes is larger. In the tropics, however, the effects of those two are relatively insignificant as illustrated in Fig. 4. The intensity of the cyclone does not vary much (about 0.5 mb) with the inclusion of either of these two effects , yet it deepens by 2 mb to 1012 mb after the consideration of gradient wind effect (Fig. 4, lower panel).

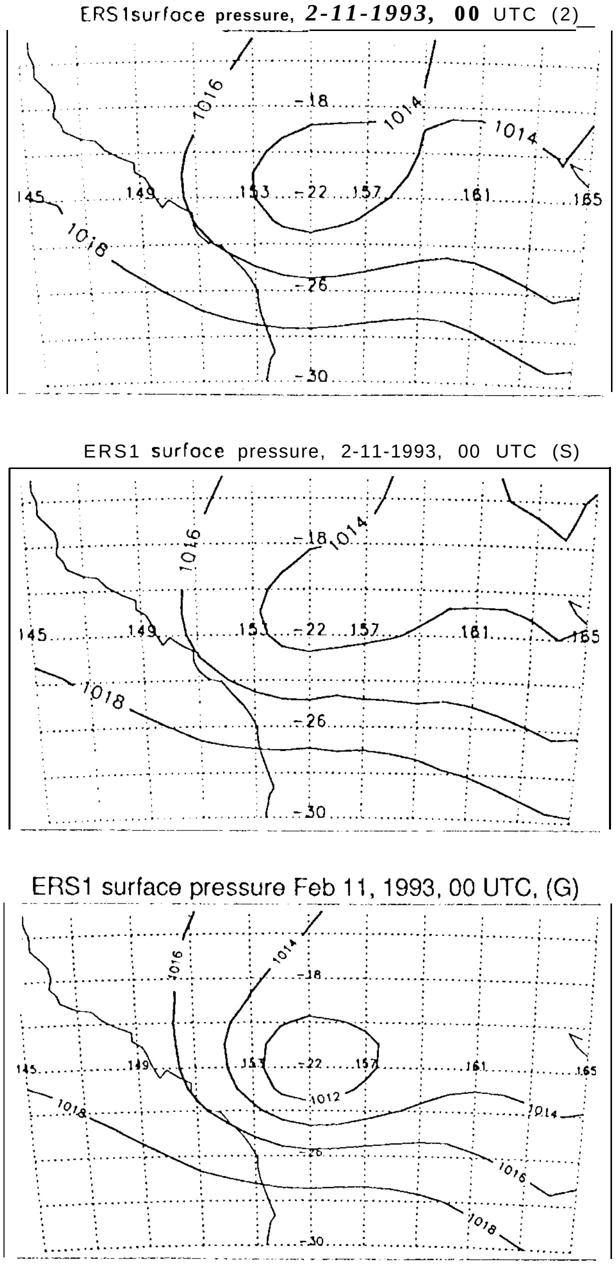

Fig. 4. Pressure fields derived from scatterometer winds with the inclusion of secondary flow (upper), stability (middle), and gradient wind (lower).

5. Conclusions

1, Data from the ERS-1 scatterometer may be used to resolve circulation of tropical cyclones, not seen in the ECMWF analyses, and can also be used to further derive the surface pressures.

2. The sea level pressure field near the tropical cyclone can be constructed using the high resolution ERS-1 surface winds and a PBL model assuming a gradient wind relationship.

3. The curvature effect on the pressure values can be more significant than stability and secondary flow, which are crucial in deriving accurate surface pressure fields in mid-latitudes.

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