# A Comparison among LATEX, NCEP, and *ERS-1* Scatterometer Winds over the Northwestern Gulf of Mexico

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ABSTRACT

Hourly wind fields for the northwestern Gulf of Mexico (here called LATEX winds) were constructed from in situ measurements for the period April 1992 through November 1994 using statistical (optimal) interpolation. Here the LATEX winds are compared with the National Centers for Environmental Prediction (NCEP) and the European Remote Sensing Satellite (*ERS-1*) scatterometer winds for the same period and region. Comparisons show no significant bias between LATEX and *ERS-1* wind speeds or directions. LATEX and *ERS-1* wind fields nearly coincide except during extreme meteorological events when *ERS-1* fields may show noncoherent patterns over distances for which coherence is expected; for those situations, LATEX winds appear more realistic. Although there is no significant bias between wind speeds, the direction bias is more than 10° between the LATEX and NCEP winds. The largest differences between LATEX and NCEP winds occurred near the coast. In summer, the NCEP and LATEX winds showed larger differences and smaller variance; for winter the reverse was true. The authors conclude from the comparisons that LATEX wind fields provided realistic and detailed surface winds that are appropriate for the study of mesoscale processes and forcing of numerical models over the Texas–Louisiana continental shelf.

## 1. Introduction

The National Oceanic and Atmospheric Administration, in cooperation with industry, provides hourly surface meteorological observations from a number of sites (platforms and buoys) in the northwestern Gulf of Mexico. Locations are indicated as NDBC (National Data Buoy Center) or C-MAN (Coastal Marine Automated Network) stations in Fig. 1. The Texas–Louisiana Shelf Circulation and Transport Processes Study (LATEX-A), sponsored by the Minerals Management Service of the Department of Interior, provided supplemental records from a suite of eight buoys (locations also shown in Fig. 1) that measured surface meteorological parameters hourly from April 1992 to November 1994. Selected airport weather stations over the coastal plain of Texas and Louisiana (Fig. 1) add to this relatively dense data network.

Using measurements from these locations, Wang (1996) constructed objectively analyzed wind fields at hourly intervals with spatial resolution of 0.5° in latitude and longitude for the Gulf of Mexico northwest of 26°S, 88°W. All observations were first corrected to 10-m height. The method of statistical interpolation, common in meteorology and oceanography, was used (Carter and Robinson 1987). These wind fields (hereafter referred to as LATEX winds) were constructed initially for the purpose of studying mesoscale oceanic events over the Texas–Louisiana continental shelf and are described and discussed in Wang et al. (1996, 1998).

Here we describe our comparison of the LATEX winds with winds derived from two other sources during the same observing period: model output winds provided by the National Centers for Environmental Prediction (NCEP, formerly the National Meteorological Center) and scatterometer winds from the European Remote Sensing satellite (*ERS-1*). Since March 1990, NCEP has made available global surface wind fields at 10-m height above sea level with 0.945° latitude and 0.937° longitude spatial resolution and 6-h intervals (0000, 0600, 1200, and 1800 UTC) from the Global Data Assimilation System (Dey 1989; Kanamitsu 1989). The 6-hourly NCEP wind fields (referred to here as NCEP winds) from April 1992 through November 1994 were used in this study.

*ERS-1* winds used in this study were produced at JPL using the C-MAN Model Fast Delivery model function (Freilich and Dunbar 1993). *ERS-1*, launched in July 1991 by the European Space Agency, carries a C-band radar to observe backscatter from the earth's surface (Francis et al. 1991). Three antennas are used to generate radar beams looking 45° forward, sideways, and backward with respect to the satellite's flight direction. These beams continuously illuminate a 500-km-wide swath as

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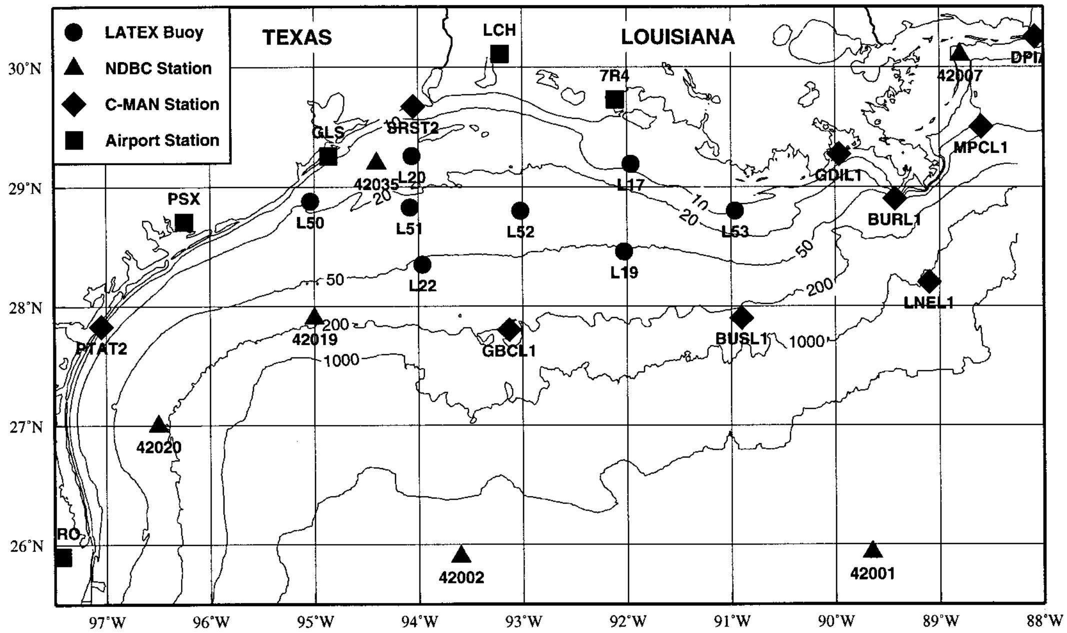


Fig. 1. Location of sites of observations used in construction of the LATEX wind fields for period April 1992–November 1994.

the satellite moves along its orbit. Wind speed and direction at 10-m height are derived from the three-antenna scatterometer for 50 km × 50 km footprints with centers spaced at 25-km separations. Neutral stability was assumed when deriving 10-m *ERS-1* winds, which could lead to some differences from LATEX winds, for which stratification was considered in correcting winds from observed to 10-m levels. The *ERS-1* scatterometer winds are subject to 180° directional ambiguity. Freilich and Dunbar made some corrections for this ambiguity in their processing. Assuming that this ambiguity is removed, the reported accuracy for *ERS-1* scatterometer winds is 2 m $s^{-1}$ or 10% (whichever is larger) for wind speeds in the range of 4–24 m $s^{-1}$ and 20° for direction. *ERS-1* wind speed derived by Freilich and Dunbar is reported with resolution of 0.6 m $s^{-1}$. A typical time interval between successive *ERS-1* observations at a fixed point is about 35 days during the time of the 41 *ERS-1* swaths examined.

Note that LATEX, NCEP, and *ERS-1* winds were produced differently. LATEX winds were constructed from hourly in situ measurements using a statistical interpolation method of objective analysis. The anemometers used on the NDBC and C-MAN stations and on LATEX buoys average for 8 min prior to the hour. Automated surface observing systems at airport weather stations report 2-min averages of 24 5-s averages of speed and direction taken prior to the hour. NCEP winds are based on a blend of data with a numerical weather forecast, with both temporal and spatial smoothing. *ERS-1* winds are temporal and spatial averages representing 50 km × 50 km areas. The *ERS-1* scatterometer measures a 500-km-wide swath with 25-km resolution. Each 25 km of the subsatellite track swath is measured for 3.76 s. Four 25 km × 25 km spots are combined to yield reported winds representing 50 km × 50 km areas; the two halves of each area were measured in successive 3.76-s periods. The LATEX wind fields are from in situ measurements that may have several sources of unknown bias and random errors arising from such factors as instrument errors, platform interference effects, and interpolation procedure. The scatterometer winds are also based on in situ (wave) conditions but are remotely sensed with large spatial and temporal gaps, and they also have inherent biases and random errors related to the measurement procedure and algorithms used to convert the measures to 10-m winds. LATEX and *ERS-1* winds have similar spatial resolutions; NCEP winds have the coarsest spatial resolution among the three datasets.

The average separation distance between nearest observing stations used to construct the LATEX winds for the area is approximately 90 km (Wang 1996). By contrast, the along-shelf and cross-shelf covariance inferred scales for LATEX wind components vary from about 150 to 450 km; monthly averages were approximately 350 km for both components for separation in either direction (Wang et al. 1998). Therefore, we believe the LATEX wind fields should well represent actual mesoscale wind features in the study area.

Our objective here is to determine how well the actual winds for this region are represented by the model-based NCEP winds and the satellite-derived *ERS-1* scatterometer winds. If such wind fields well represent the local winds in the Texas–Louisiana shelf domain, they could be used in the study of air–sea interactions and wind effects on oceanic phenomena (in place of analyzed wind fields produced from in situ observations at much extra cost and effort). Moreover, if the representation is good for this shelf domain, it may be good in other such coastal plane locales. Finally, the NCEP wind field product is less well resolved spatially than either *ERS-1* or LATEX products but has the advantage that it is not so limited temporally (*ERS-1* being available only about every 35 days and LATEX winds only for a period of 32 months). Thus, if NCEP winds are shown to provide good representations, they offer a long-term wind product for studying air–sea exchanges and oceanic phenomena.

Our approach to determining how well the NCEP and *ERS-1* winds represent the local wind regime is to compare them with the LATEX winds, which we believe do well represent the real winds.

To the authors' knowledge, previous evaluations of satellite scatterometer winds were performed either by comparisons with in situ observations at individual points over limited periods or with averaged values from operational weather prediction models or ship observations (Jones et al. 1982; Guymer 1983; Halpern et al. 1996). In this study, evaluation was performed by comparison at the *ERS-1* grid points for the 41 selected swaths (Table 1).

TABLE 1. Beginning times for each of the 41 selected *ERS-1* swaths over the region and number of grid points in the swath for which wind observations were available.

| Swath | Time (UTC) | Date | No. of points |
|---|---|---|---|
| 1 | 0429 | 03 Jul 1992 | 222 |
| 2 | 1649 | 03 Jul 1992 | 186 |
| 3 | 0421 | 16 Jul 1992 | 84 |
| 4 | 0438 | 07 Nov 1992 | 112 |
| 5 | 1658 | 07 Nov 1992 | 75 |
| 6 | 0501 | 19 Nov 1992 | 62 |
| 7 | 0429 | 20 Nov 1992 | 276 |
| 8 | 1635 | 30 Nov 1992 | 52 |
| 9 | 0415 | 08 Feb 1993 | 48 |
| 10 | 0452 | 10 Feb 1993 | 184 |
| 11 | 0421 | 11 Feb 1993 | 139 |
| 12 | 1646 | 14 Feb 1993 | 264 |
| 13 | 1614 | 15 Feb 1993 | 71 |
| 14 | 0432 | 17 Feb 1993 | 263 |
| 15 | 1652 | 17 Feb 1993 | 171 |
| 16 | 1620 | 18 Feb 1993 | 158 |
| 17 | 1658 | 20 Feb 1993 | 74 |
| 18 | 1626 | 21 Feb 1993 | 241 |
| 19 | 0450 | 26 Feb 1993 | 228 |
| 20 | 0418 | 27 Feb 1993 | 99 |
| 21 | 0455 | 01 Mar 1993 | 135 |
| 22 | 0424 | 02 Mar 1993 | 183 |
| 23 | 0429 | 05 Mar 1993 | 278 |
| 24 | 1629 | 12 Mar 1993 | 288 |
| 25 | 1634 | 15 Mar 1993 | 299 |
| 26 | 0421 | 18 Mar 1993 | 141 |
| 27 | 1640 | 18 Mar 1993 | 302 |
| 28 | 1658 | 27 Mar 1993 | 75 |
| 29 | 1626 | 28 Mar 1993 | 241 |
| 30 | 1640 | 01 Jul 1993 | 304 |
| 31 | 0504 | 06 Jul 1993 | 29 |
| 32 | 1652 | 07 Jul 1993 | 171 |
| 33 | 1631 | 14 Jul 1993 | 308 |
| 34 | 0450 | 16 Jul 1993 | 230 |
| 35 | 0455 | 19 Jul 1993 | 135 |
| 36 | 0501 | 22 Jul 1993 | 58 |
| 37 | 1649 | 23 Jul 1993 | 219 |
| 38 | 0435 | 26 Jul 1993 | 304 |
| 39 | 1655 | 26 Jul 1993 | 124 |
| 40 | 0441 | 26 Jul 1993 | 298 |
| 41 | 1629 | 30 Jul 1993 | 289 |

## 2. Comparisons between LATEX and NCEP winds

LATEX winds have finer spatial resolution and smaller temporal intervals than NCEP winds. To avoid bias in comparisons, we produced by statistical interpolation LATEX winds at the same grid points and times as NCEP winds. Then, we obtained mean winds for the entire period and for seasons by averaging the 6-hourly values at each grid point for both wind sets.

For a vector, the mean and variability over some period can be described by its vector mean and a variance ellipse. The major and minor axes of the ellipse are orthogonal and called principal axes along which the maximum and minimum variances occur. The covariance between the components along the two principal axes is null. This description is adopted here to describe mean wind fields and mean differences between wind fields.

### *a. Long-term means, differences, and variances*

LATEX winds averaged over the period April 1992 to November 1994 at NCEP grid points are pictured in the upper panel of Fig. 2; NCEP winds averaged over the same period are shown in the middle panel. These two vector-averaged fields generally agree. Both show east to southeast winds; winds over the western region are stronger and more southeasterly than in the east. NCEP winds are somewhat stronger than LATEX winds and have larger southerly components east of the border between Texas and Louisiana. Also, variances of NCEP winds are generally larger than for LATEX winds. For both fields, north–south variances are larger than east–west, particularly in the west. However, ratios of the major to minor axis in NCEP winds tend to be closer to unity.

The lower panel of Fig. 2 shows the mean 6-h vector differences between NCEP and LATEX winds. The differences were averaged over the period April 1992–November 1994 at each NCEP grid point. Differences are generally less than 1.5 m $s^{-1}$. Larger differences are found near the coast, particularly south of Louisiana. Fluctuations of mean differences show some preference for north–south orientation near the coast. Note that magnitudes of the fluctuations exceed those of mean values by factors of 3–4. However, the variability of the differences as less by a factor of 2 than the variability of either individual wind field.

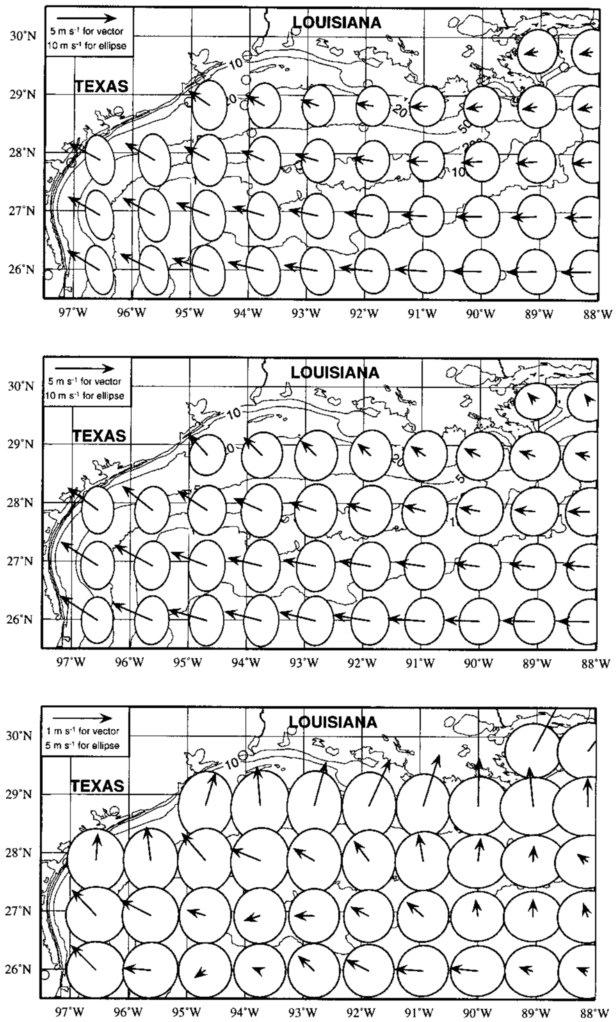


FIG. 2. Vector-averaged LATEX winds (upper panel), NCEP winds (middle panel), and NCEP minus LATEX winds (lower panel) with variances for the period April 1992–November 1994.

We tested the significance of the differences using Student's t-test (Fig. 3). For the eastward wind component ($u$), the level of significance is about 0.9 near the Texas coast decreasing to the southeast and east. For the southerly wind component ($v$), the significance level of differences is largest near the Louisiana coast, decreasing southward and to the southeast. In Fig. 3 we highlight with heavy lines the 80% significance level. This indicates that the differences between LATEX and NCEP winds are significant nearshore, although the differences remain less than 1.5 m s$^{-1}$ in the mean.

Winds vary rapidly in time. Averaging NCEP and LATEX wind fields results in smooth fields with similar patterns, but instantaneous fields may have large differences. To examine instantaneous differences, the 6-hourly NCEP and LATEX winds were compared. Speed differences were divided into 1 m s$^{-1}$ bins ranging from $-16$ to 16 m s$^{-1}$; direction differences were in 10° bins from $-180°$ to 180°. Figure 4 shows histograms of differences in speed and direction between the fields. For speed, there is little if any systematic difference. For direction, measured positive counterclockwise, the difference peak is centered at $-10°$, implying a clockwise bias of NCEP winds relative to LATEX winds. Overall, 70% of the speed differences are less than 2 m s$^{-1}$ and 50% of the direction differences are less than 20°.

### *b. Seasonal means, variances, and differences*

Seasonal patterns for LATEX and NCEP wind fields are quite similar, but there are differences in detail. Figure 5 shows mean seasonal difference fields along with their fluctuations. March–May is taken to represent the spring season; June–August represents summer; etc. Note that spring of 1992 is represented by only April and May, and there are only two winters represented, based on the period April 1992–November 1994.

Maximum differences occur during summer, with values near 2 m s$^{-1}$ over the inner shelf; minimum differences occur during winter, most of them less than 0.5 m s$^{-1}$. In contrast, fluctuations in summer are much smaller than those in winter; the maximum major axis (standard deviation along that axis) is less than 3 m s$^{-1}$ in summer but more than 4 m s$^{-1}$ in winter. The speed differences in spring and fall are between the extremes of summer and winter. As to direction differences, NCEP winds tend to have a larger south (east) component in spring (fall) than the LATEX winds. In summer and winter the direction differences appear somewhat more random.

The larger fluctuations of the winter differences can be explained by the fact that there are many frontal incursions in this season, as many as nine per month (DiMego et al. 1976; Henry 1979), together with the fact that frontal positions in the NCEP and LATEX fields do not agree well in detail, causing larger differences of wind speeds and directions near the fronts. Figure 6 illustrates such disagreement; NCEP and LATEX wind fields are pictured at the time of a frontal passage (0600 UTC 4 November 1992). The front situated across the shelf was located about 1° farther east in the NCEP than in the LATEX field. Behind the front (to the northwest) LATEX winds are north to northwesterly, but NCEP winds are northwest and of larger magnitudes. Ahead of the fronts, wind speeds are comparable, but NCEP winds have larger south components than LATEX winds. This disagreement is not uncommon based on the frontal passages examined.

In response to the suggestion of one reviewer, we briefly examined the variability of LATEX winds in comparison to that of NCEP winds as a function of time of day and for three locations in the study region: nearshore off south Texas (point 1; 27°S, 96.5°W); nearshore off Louisiana (point 2; 29°S, 92°W); and off the shelf, south of point 2 (point 3; 26°S, 92°W). Autospectra constructed by season show significant peaks near di-

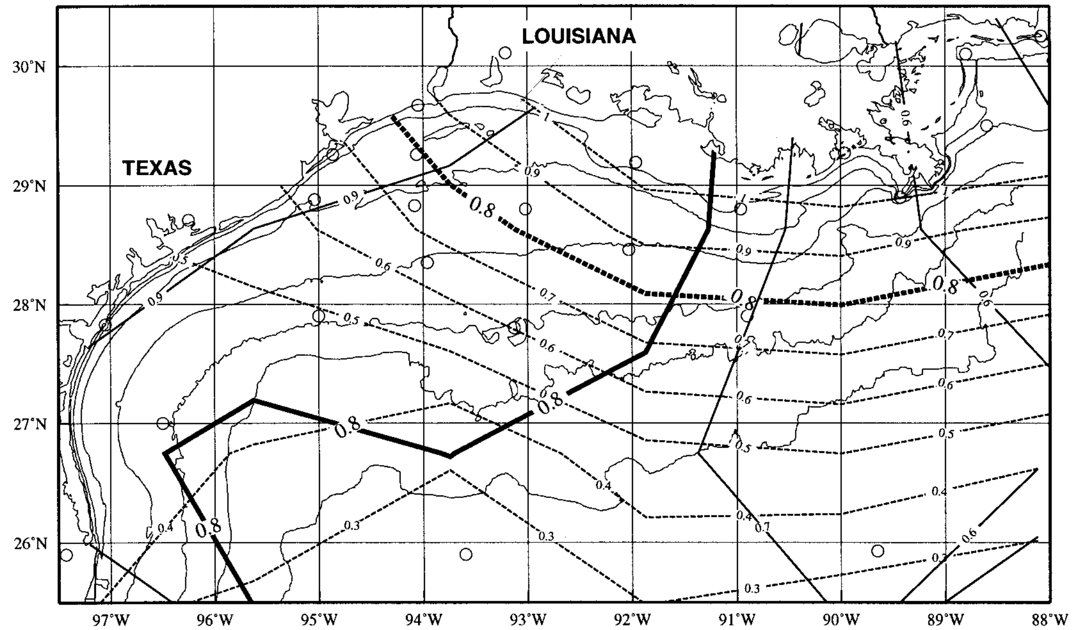


FIG. 3. Significance levels (based on Student's t-test) for differences between LATEX and NCEP wind components. Solid lines are for eastward components; dashed lines are for northward components.

urnal for both wind fields at each location during summer and show less energy during fall. No such peaks are seen in winter and are only marginally evident at point 1 during spring.

Examination of vector hodographs and time series of components for 16–46-h bandpassed winds reveals that the motions contributing to those energetic peaks are diurnal clockwise rotations. The hourly LATEX winds generally are phase locked with the sun at all positions examined. The maximum along-shelf components directed upcoast (in a direction from the Rio Grande to the Mississippi River) occurs near 1800 LT and the maximum offshore flow occurs near 0000 LT. The NCEP winds do not seem so clearly phase locked and at times are out of phase with the LATEX winds. However, a careful comparison is difficult because the NCEP winds are only at 6-h intervals.

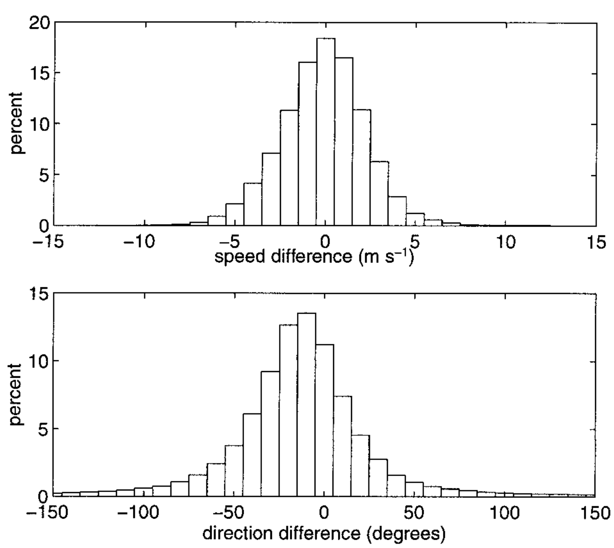


FIG. 4. Histograms of differences (NCEP minus LATEX winds) based on 6-hourly values at 194 095 grid points for the period April 1992–November 1994.

Autospectra show that during summer for diurnal frequency, the NCEP winds have much more energy than the 6-hourly LATEX winds at point 2, more energy at point 1, and about the same energy at point 3. Comparison of hourly winds is not possible. As suggested by our reviewer, this may reflect differences between modeled and actual heat fluxes and coast lines and could contribute to the fact that the difference between NCEP and LATEX winds is larger near shore than elsewhere. A complete examination of differences within the daily cycle is beyond the scope of this study and impractical because only 6-hourly NCEP winds are available.

Histograms of speed and direction differences between the two wind sets were examined for each season, based on some 194 095 sets of differences—for every 6 h at all NCEP grid points. Wind speed differences were centered at 0 m s$^{-1}$ in all seasons (as for Fig. 4). However, wind direction histograms peak at $-10°$ in summer and fall and $-20°$ in spring and winter; these directional differences are significant at 95% or greater for all seasons based on Student's t-test.

## 3. Comparison with *ERS-1* scatterometer winds

Winds from 41 *ERS-1* swaths that passed over the Texas–Louisiana continental shelf during five selected

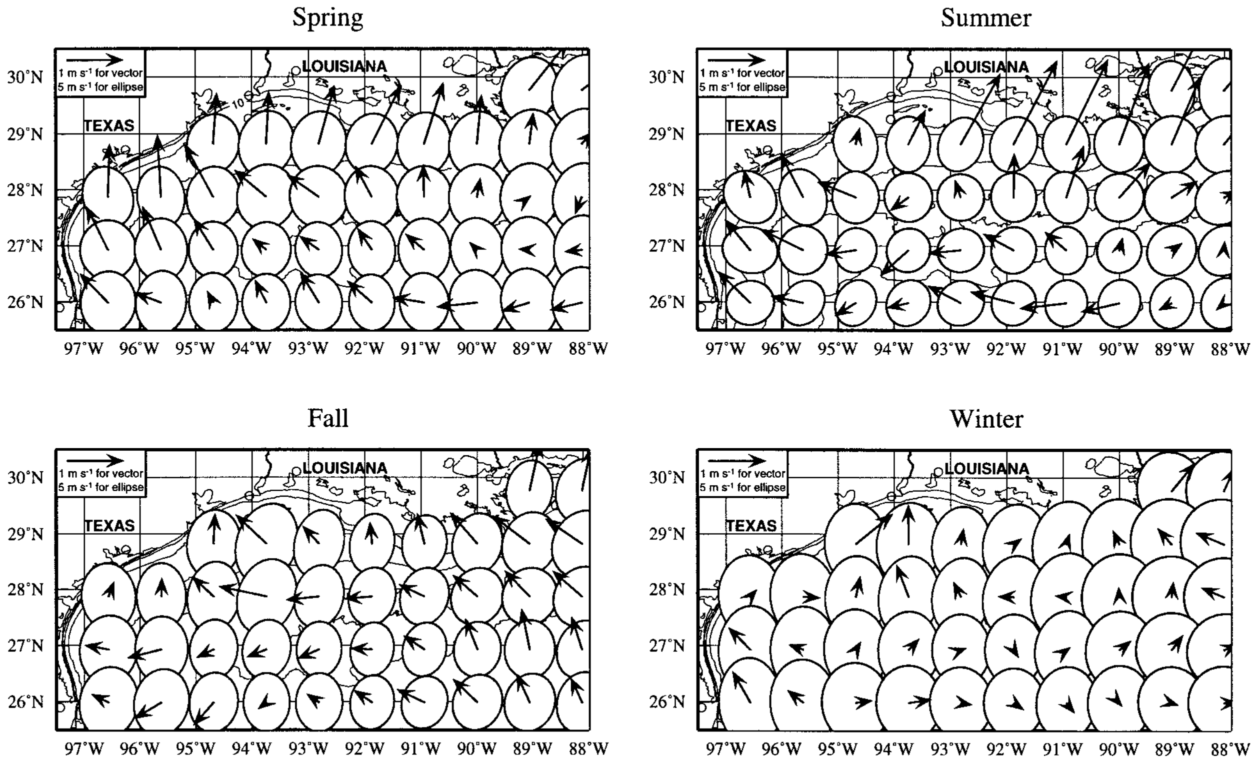


FIG. 5. Seasonal vector-averaged difference between LATEX and NCEP wind fields (NCEP minus LATEX) with variances.

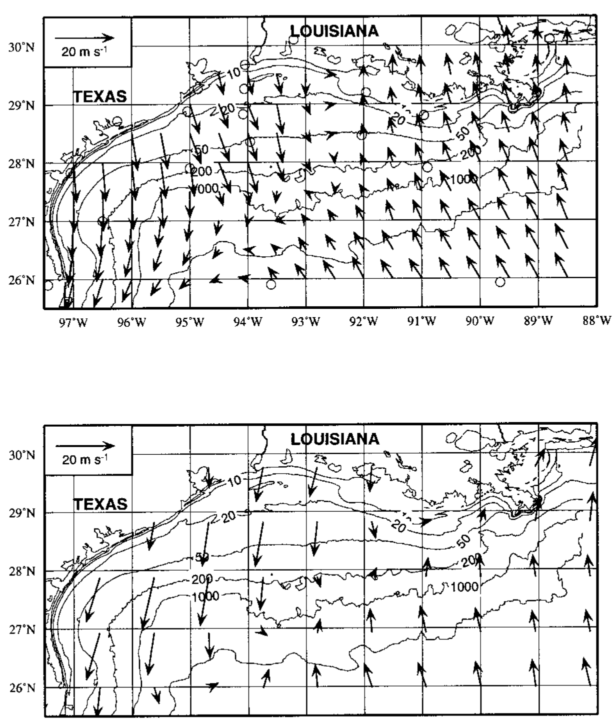


FIG. 6. LATEX (upper panel) and NCEP (lower panel) winds at 0600 UTC 4 November 1992.

months were examined. The months selected are March 1993, representing spring; July 1992 and 1993, representing summer; November 1992, representing fall; and February 1993, representing winter. If either speed or direction was missing from the *ERS-1* data at a grid point, that point was not included in the comparison. LATEX winds were statistically interpolated to *ERS-1* grid points at the beginning of an hour, so there is less than 1-h time difference between *ERS-1* and LATEX winds. NCEP winds during the times of these orbits also were interpolated using a bicubic spline to *ERS-1* grid points to enable comparison among all three wind fields. Table 1 shows beginning times of the 41 swaths and corresponding numbers of grid points. In total, winds were available for comparison at a total of 7259 grid points within the *ERS-1* swaths.

Although many 180° direction ambiguities in the *ERS-1* winds were removed by Freilich and Dunbar (1993), some remain. To correct these, we examined *ERS-1* wind direction in relation to LATEX wind direction at the same grid point and closest time and, if the difference was greater than 90°, we added 180° to the *ERS-1* wind direction. Corrections were necessary for 17.8% of the wind vectors included in the 41 satellite swaths considered.

### *a. Overall comparison*

The statistics of the comparisons between LATEX winds and *ERS-1* satellite winds at the 7259 grid points

TABLE 2. Statistical comparison of LATEX and *ERS-1* winds for the 41 selected *ERS-1* swaths.

| Swath | Percent within 2 m s$^{-1}$ | Percent within 20° | Speed difference (m s$^{-1}$) | Direction difference (deg) | rms speed (m s$^{-1}$) | rms direction (deg) | Std dev $\Delta u$ | Std dev $\Delta v$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 91 | 76 | −0.8 | −10 | 1.1 | 16 | 0.93 | 1.26 |
| 2 | 51 | 36 | 2.1 | −6 | 3.0 | 38 | 2.42 | 2.64 |
| 3 | 92 | 24 | 0.7 | 33 | 1.1 | 43 | 1.60 | 1.93 |
| 4 | 99 | 99 | 0.3 | 6 | 0.5 | 9 | 1.05 | 0.67 |
| 5 | 89 | 72 | −0.6 | 3 | 1.3 | 16 | 1.34 | 1.93 |
| 6 | 53 | 92 | 1.8 | 7 | 1.9 | 9 | 0.61 | 0.97 |
| 7 | 78 | 67 | 0.3 | 3 | 1.9 | 18 | 2.23 | 2.70 |
| 8 | 100 | 88 | 0.0 | −4 | 0.7 | 15 | 0.82 | 1.40 |
| 9 | 65 | 8 | 1.1 | −29 | 1.7 | 30 | 1.36 | 0.86 |
| 10 | 71 | 93 | 1.2 | 4 | 1.9 | 12 | 1.57 | 1.54 |
| 11 | 93 | 34 | 0.2 | −28 | 1.1 | 31 | 1.74 | 1.10 |
| 12 | 95 | 70 | −0.4 | 0 | 1.2 | 30 | 1.63 | 2.03 |
| 13 | 52 | 97 | 0.2 | 5 | 2.2 | 10 | 1.78 | 1.67 |
| 14 | 75 | 46 | 0.1 | −17 | 1.9 | 39 | 2.39 | 4.56 |
| 15 | 68 | 99 | −1.1 | 3 | 1.6 | 7 | 0.94 | 0.98 |
| 16 | 98 | 100 | −0.4 | −3 | 0.9 | 6 | 0.82 | 0.79 |
| 17 | 96 | 100 | 0.0 | 1 | 0.9 | 7 | 0.70 | 0.92 |
| 18 | 90 | 81 | 0.1 | −3 | 1.3 | 18 | 1.35 | 1.51 |
| 19 | 85 | 74 | 0.7 | 1 | 1.3 | 21 | 1.43 | 1.23 |
| 20 | 99 | 88 | −0.4 | −1 | 0.8 | 13 | 1.57 | 1.30 |
| 21 | 28 | 56 | 2.8 | 10 | 3.1 | 19 | 1.90 | 2.91 |
| 22 | 72 | 50 | −0.3 | −20 | 1.9 | 21 | 1.27 | 1.80 |
| 23 | 91 | 57 | 0.4 | −9 | 1.2 | 20 | 1.33 | 1.82 |
| 24 | 25 | 17 | 3.8 | 22 | 5.5 | 50 | 6.04 | 7.07 |
| 25 | 69 | 96 | 1.5 | −2 | 2.0 | 10 | 1.62 | 1.30 |
| 26 | 64 | 99 | 1.7 | 4 | 1.9 | 7 | 1.42 | 0.94 |
| 27 | 87 | 77 | 0.9 | 8 | 1.2 | 17 | 1.21 | 1.21 |
| 28 | 100 | 28 | 0.1 | 24 | 0.6 | 30 | 0.97 | 1.53 |
| 29 | 97 | 84 | 0.8 | 4 | 1.1 | 17 | 0.80 | 0.95 |
| 30 | 89 | 54 | −0.6 | 19 | 1.4 | 34 | 1.59 | 1.58 |
| 31 | 90 | 100 | 1.2 | 0 | 1.3 | 4 | 0.67 | 0.56 |
| 32 | 83 | 88 | −0.7 | 1 | 1.4 | 15 | 1.42 | 1.49 |
| 33 | 85 | 56 | 0.3 | 1 | 1.4 | 30 | 1.39 | 1.37 |
| 34 | 90 | 90 | −0.4 | −4 | 1.3 | 13 | 1.19 | 1.17 |
| 35 | 92 | 92 | −0.8 | −1 | 1.1 | 17 | 0.57 | 1.32 |
| 36 | 96 | 96 | 0.6 | 3 | 1.1 | 13 | 0.65 | 1.22 |
| 37 | 94 | 77 | −0.7 | 2 | 1.1 | 19 | 1.25 | 1.14 |
| 38 | 97 | 72 | 0.0 | −1 | 0.8 | 21 | 1.43 | 0.96 |
| 39 | 94 | 11 | 0.4 | 34 | 1.0 | 60 | 1.25 | 1.55 |
| 40 | 98 | 61 | −0.1 | 0 | 0.6 | 25 | 1.35 | 1.36 |
| 41 | 55 | 37 | 2.2 | 19 | 2.7 | 42 | 2.24 | 2.04 |

are summarized in Table 2. Among the 41 swaths, there are 21 for which above 90% of grid points have speed difference less than 2 m s$^{-1}$ and 13 swaths for which above 90% of the grid points have direction difference less than 20°. Most of the swaths have mean speed difference less than 1 m s$^{-1}$ and mean direction difference less than 10°, and there are 36 swaths with rms speed difference less than 2 m s$^{-1}$ and 25 swaths with rms direction difference less than 20°. Considering all grid points, 81% show good agreement in speed, 67% in direction, and 57% in both speed and direction. The mean speed difference (*ERS-1* minus LATEX) is 0.5 m s$^{-1}$, and the mean direction difference is 2°; the rms speed difference is 1.9 m s$^{-1}$ and the rms direction difference is 26°.

Also included in Table 2 are the standard deviations of differences between *ERS-1* and LATEX $u$ and $v$ components for each swath. The zonal component $u$ is positive toward the east; $v$ is the meridional component, positive toward the north. Considering $u$ and $v$ values from all swaths gives standard deviations of 2.19 and 2.45 m s$^{-1}$ for $\Delta u$ and $\Delta v$, respectively. During swaths 7, 14, and 24, the shelf was under the influence of extreme atmospheric events. For example, swath 24 occurred during the passage of a major cyclone (discussed in the next section as "the Storm of the Century"); $u$ and $v$ differences were very large for reasons discussed in the next section. For these three swaths the average deviations for $\Delta u$ and $\Delta v$ were 4.21 and 5.31 m s$^{-1}$. Removing these three cases reduces the standard deviations to 1.74 and 1.75 m s$^{-1}$. For each swath of *ERS-1* winds we computed correlations between the *ERS-1* and LATEX wind components. Correlations of both $u$ and $v$ components (not shown in Table 2) were significant at the 95% level or greater for 34 and 36 of the 41 swaths, respectively. One case of poor $u$ correlation

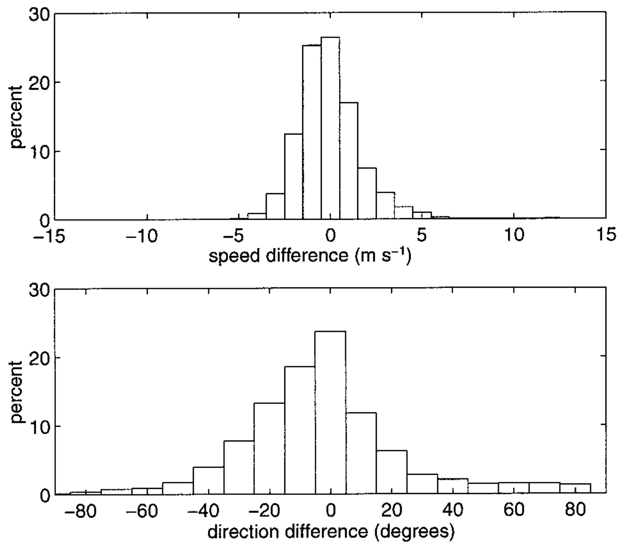


FIG. 7. Histograms of differences between LATEX and *ERS-1* winds (*ERS-1* minus LATEX).

is attributed to the presence of an extreme weather event over the shelf.

Histograms of differences in wind speed and direction are shown in Fig. 7 based on data from all 41 selected swaths. Speed differences were divided into 1 m $s^{-1}$ bins ranging from −16 to 16 m $s^{-1}$, and direction differences into 10° bins from −90° to 90°. For wind speed the difference peak is centered at 0 m $s^{-1}$, and for direction it is at 0°, although both histograms are skewed toward larger negative than positive near-central numbers and a longer tail of positive than negative differences. [We also examined histograms of differences by season. Although there appears to be some variation between seasons, the number of samples in a given season (two months for summer and only one month for other seasons) is small and the differences are not likely significant.] For comparison with Fig. 7, there is a 10°–20° bias in direction differences between NCEP and LATEX winds (see Fig. 4).

Table 3 presents results of comparisons among LATEX, *ERS-1*, and NCEP winds at *ERS-1* grid points in the 41 swaths. The correlations of wind components are all significantly different from zero at the 99.95% level. Based on this table, it appears that agreement is best between LATEX and *ERS-1* winds and is poorest between LATEX and NCEP winds.

For the three wind fields, spatially averaged vector winds were computed over the geographic extent of each of the 41 *ERS-1* swaths. Table 4 summarizes the results. For 10 of the 41 swaths, *ERS-1* wind directions differed from LATEX by more than 20°; for 4 swaths, wind speed differences between *ERS-1* and LATEX winds were larger than 2 m $s^{-1}$. By contrast, for 17 swaths, NCEP wind directions differed from LATEX by more than 20°, and for 11 swaths, speed differences between NCEP and LATEX winds were larger than 2 m $s^{-1}$.

TABLE 3. Comparison of speed and direction differences among LATEX, *ERS-1*, and NCEP winds averaged over all grid points for the 41 selected *ERS-1* swaths.

| | *ERS-1* vs LATEX | *ERS-1* vs NCEP | NCEP vs LATEX |
|---|---|---|---|
| Mean speed difference (m $s^{-1}$) | 0.5 | −0.7 | 1.2 |
| rms speed difference (m $s^{-1}$) | 1.9 | 2.3 | 2.6 |
| Mean direction difference (°) | 2.6 | 8.6 | −4.4 |
| rms direction difference (°) | 26.1 | 27.8 | 38.3 |
| Std dev $\Delta u$ (m $s^{-1}$) | 2.2 | 2.7 | 3.0 |
| Std dev $\Delta v$ (m $s^{-1}$) | 2.5 | 2.7 | 3.2 |
| Correlation ($u$) | 0.8 | 0.7 | 0.6 |
| Correlation ($v$) | 0.9 | 0.9 | 0.8 |

TABLE 4. Comparison of LATEX, *ERS-1*, and NCEP winds averaged spatially over the 41 selected *ERS-1* swaths.

| Swath | LATEX speed (m $s^{-1}$) | LATEX direction (deg) | *ERS-1* speed (m $s^{-1}$) | *ERS-1* direction (deg) | NCEP speed (m $s^{-1}$) | NCEP direction (deg) |
|---|---|---|---|---|---|---|
| 1 | 6.7 | 133 | 5.9 | 123 | 5.9 | 130 |
| 2 | 4.2 | 112 | 6.3 | 106 | 6.3 | 129 |
| 3 | 4.5 | 124 | 5.1 | 157 | 5.1 | 123 |
| 4 | 8.5 | −127 | 8.7 | −122 | 8.7 | −132 |
| 5 | 8.2 | −150 | 7.6 | −147 | 11.6 | −166 |
| 6 | 6.3 | 139 | 8.0 | 145 | 6.3 | 13 |
| 7 | 9.2 | 154 | 9.5 | 157 | 8.8 | 132 |
| 8 | 5.7 | 20 | 5.7 | 16 | 6.0 | 143 |
| 9 | 6.0 | −50 | 7.0 | −79 | 5.9 | −66 |
| 10 | 8.2 | 132 | 9.4 | 136 | 9.2 | 126 |
| 11 | 7.6 | 145 | 7.9 | 117 | 7.9 | 95 |
| 12 | 6.2 | 70 | 5.9 | 70 | 9.3 | 145 |
| 13 | 9.3 | 130 | 9.4 | 135 | 10.6 | 103 |
| 14 | 8.6 | −117 | 8.6 | −134 | 10.4 | −126 |
| 15 | 8.5 | −136 | 7.4 | −134 | 9.0 | −133 |
| 16 | 9.1 | −104 | 8.6 | −107 | 9.8 | −102 |
| 17 | 6.2 | 89 | 6.2 | 90 | 10.8 | 96 |
| 18 | 5.8 | 88 | 5.8 | 86 | 7.2 | 64 |
| 19 | 5.0 | −103 | 5.7 | −101 | 9.8 | −106 |
| 20 | 9.5 | −108 | 9.1 | −109 | 10.1 | −116 |
| 21 | 7.9 | 143 | 10.7 | 153 | 7.4 | 134 |
| 22 | 8.9 | 134 | 8.7 | 115 | 8.5 | 111 |
| 23 | 6.0 | −25 | 6.4 | −34 | 7.2 | −64 |
| 24 | 8.6 | −15 | 12.3 | 8 | 11.5 | −14 |
| 25 | 8.3 | 145 | 9.8 | 144 | 11.0 | 144 |
| 26 | 10.9 | −97 | 12.6 | −93 | 12.6 | −114 |
| 27 | 4.9 | 59 | 5.8 | 66 | 8.2 | 61 |
| 28 | 5.5 | −108 | 5.6 | −84 | N/A | N/A |
| 29 | 3.7 | −53 | 4.5 | −49 | 5.2 | 42 |
| 30 | 4.5 | 72 | 3.9 | 91 | 5.0 | 123 |
| 31 | 8.5 | 123 | 9.7 | 123 | 8.4 | 117 |
| 32 | 7.8 | 116 | 7.1 | 117 | 7.4 | 122 |
| 33 | 3.5 | 132 | 3.7 | 133 | 5.3 | 141 |
| 34 | 5.6 | 120 | 5.2 | 116 | 6.1 | 106 |
| 35 | 5.5 | 142 | 4.6 | 141 | 6.2 | 99 |
| 36 | 5.9 | 113 | 6.5 | 117 | 6.5 | 100 |
| 37 | 5.5 | 72 | 4.8 | 74 | 5.7 | 95 |
| 38 | 4.1 | 146 | 4.1 | 145 | 3.8 | 129 |
| 39 | 2.2 | 90 | 2.5 | 124 | 6.0 | 151 |
| 40 | 4.4 | 138 | 4.3 | 138 | 1.7 | 17 |
| 41 | 1.5 | −13 | 3.6 | 6 | 2.3 | −47 |

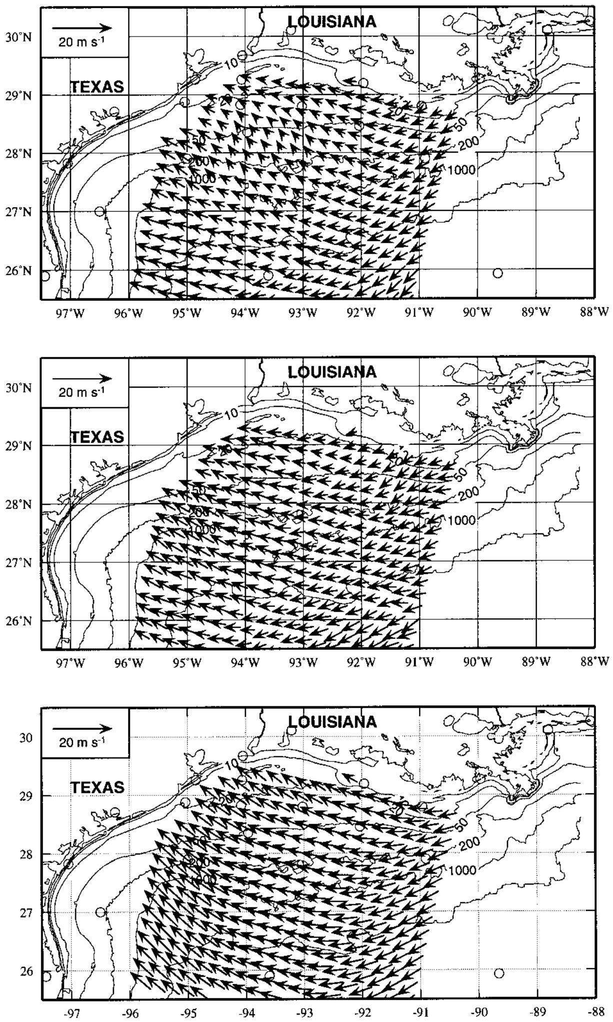


FIG. 8. LATEX (upper panel), *ERS-1* (middle panel), and NCEP winds (lower panel) at 1700 UTC 18 March 1993.

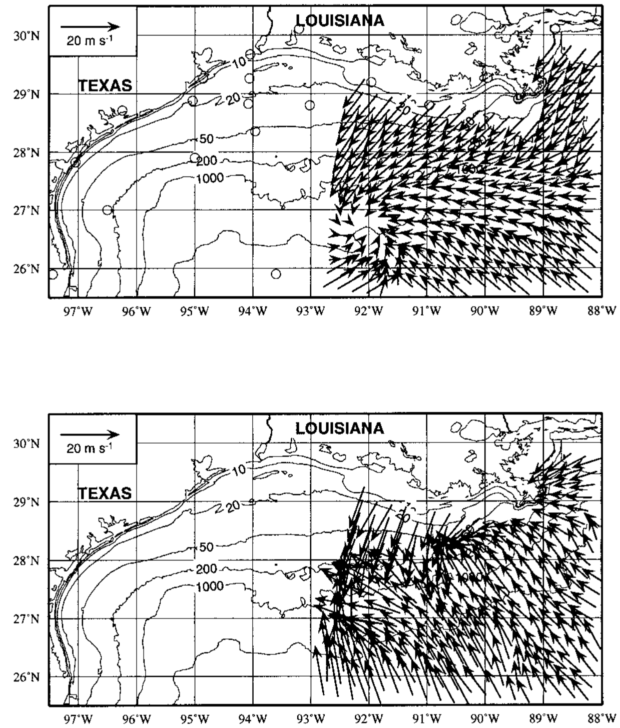


FIG. 9. LATEX winds at 1700 UTC 12 March 1993 (upper panel); *ERS-1* winds at 1629 UTC 12 March 1993 (lower panel).

### b. Comparisons of instantaneous fields

Global statistics provide a good general characterization of differences between these three wind fields but fail to give a complete picture. We compared LATEX, *ERS-1*, and NCEP wind fields for numerous synoptic situations to gain more insight into differences. Figure 8 shows an example comparison. At that time, winds over the eastern edge of the swath were northeastward, turning clockwise with increasing distance to the west. Both LATEX and *ERS-1* fields show a sharp spatial change in direction over the eastern part of the swath; speeds are comparable for these two fields. The change in direction in the NCEP field is smoother, probably because of the larger spatial scales used in the NCEP analysis. Moreover, the NCEP speeds are larger than LATEX or *ERS-1* speeds.

During the LATEX field period, there were many extreme weather events for which comparisons could be made near the operative limits of the *ERS-1*. Figure 9 shows a comparison between LATEX and *ERS-1* winds for the case of a well-developed cyclone. At 1700 UTC 12 March 1993, a strong storm called the Storm of the Century (Hsu 1993; NOAA 1993) was centered at 26.6°N and 92°W. Counterclockwise rotation around the eye of the storm is seen clearly in the LATEX wind field. Wind speeds around the eye of the storm were more than 15 m s$^{-1}$. Clear directional ambiguities (180°) were removed from the *ERS-1* wind field. Although *ERS-1* wind speeds are comparable with LATEX winds, no clear coherent cyclonic pattern is evident, possibly due to the intense rainfall that makes remote sensing by the scatterometer difficult.

### c. Dependence of wind differences on wind speeds

Dependence of speed and direction differences on wind speeds was examined for bias and scatter between *ERS-1* and LATEX winds. Scatterplots of the speed and direction differences between *ERS-1* and LATEX winds as a function of LATEX wind speed for the 41 *ERS-1* swaths are shown in Fig. 10. Also shown are linear regressions and 95% confidence intervals for the regressions. The LATEX wind speed range examined varies from 0 to 13 m s$^{-1}$. At moderate speeds (around 9 m s$^{-1}$) mean differences (i.e., bias) for both speed and direction are small, close to zero. On average, *ERS-1* slightly overestimates speed for values lower than about 9 m s$^{-1}$ and underestimates high speeds. For example,

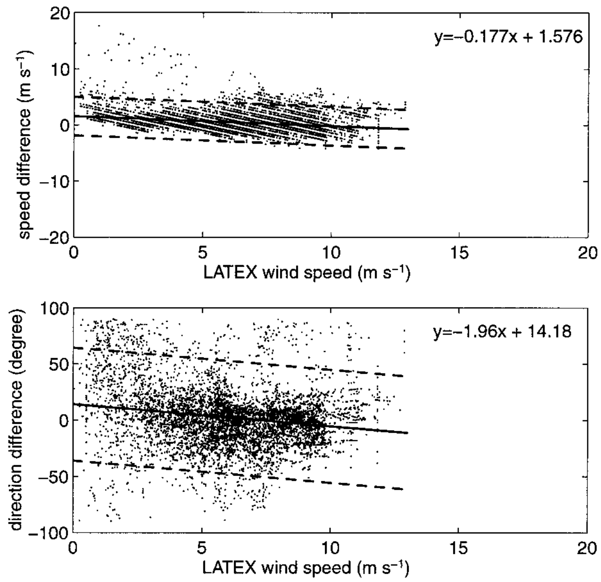


FIG. 10. *ERS-1* minus LATEX wind speeds and directions (positive counterclockwise) as functions of LATEX wind speed.

at 2 m $s^{-1}$ the *ERS-1* wind is greater than the LATEX wind by about 1.2 m $s^{-1}$ and directions differ by some 10°; at 13 m $s^{-1}$, the *ERS-1* wind is less than the LATEX wind by about 0.7 m $s^{-1}$ and directions differ by some 11°. As seen here and discussed previously, the individual differences between *ERS-1* and LATEX wind vectors can be rather large; from Table 3 the rms speed difference was 1.9 m $s^{-1}$ and the rms direction difference was 26°.

## 4. Summary and conclusions

The LATEX wind fields, prepared from surface observations using an optimal interpolation technique, were compared with two other wind fields for the same time and location. One was an analyzed surface wind field from the NCEP; the other field was derived by Freilich and Dunbar (1993) using data from the *ERS-1* scatterometer. The LATEX winds extend throughout the period from April 1992 to November 1994 and provide realistic and detailed surface wind fields for use in the study of mesoscale processes and forcing numerical models over the Texas–Louisiana shelf. Either the gridded LATEX wind fields or the controlled measurements from which they were prepared are available from the authors.

The purpose of our comparison of NCEP and *ERS-1* wind products with LATEX wind products was to assess how well the former products represent the true wind regime, at least for this area.

Differences between the LATEX winds and NCEP winds were largest near the coast. Statistics showed that there was no significant bias for wind speed between the two wind sets, but the direction of the NCEP winds were biased approximately 10° clockwise relative to LATEX winds. The average standard deviations of differences in both $u$ and $v$ components between LATEX and NCEP winds are approximately 3 m $s^{-1}$ (Table 3). Comparing fields during frontal passages showed that fronts were propagated unrealistically faster and spatial scales were larger in NCEP fields than in LATEX fields.

Comparisons with *ERS-1* scatterometer winds indicated that there was no significant bias for either wind speed and direction between the LATEX and *ERS-1* winds. Comparing $u$ and $v$ components between LATEX and *ERS-1* winds yields standard deviations of 2.2–2.5 m $s^{-1}$ (Table 3). The *ERS-1* wind fields appear not to represent the physical situation very well in cases of extreme atmospheric events and for swaths very near shore.

Although *ERS-1* winds agree better than NCEP winds with LATEX winds for most situations compared, the NCEP product still offers the obvious advantage of continuing operational coverage at regular time intervals. Offered here are estimates of errors one might expect when using the NCEP product.

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