AN ARBITRARY METHOD OF SEPARATING TROPICAL AIR FROM "RETURN FLOW" POLAR AIR

W. K. Henry
Texas A&M University

Abstract

An easy, but arbitrary, method of separating returning polar air from tropical air along the Texas coast in winter is discussed. An equivalent temperature of 331 K was selected as the dividing point. Included is a discussion of the frequency of initial polar air, return flow polar air, and tropical air along the Texas coast.

1. INTRODUCTION

During the winter season cold fronts move off the Gulf Coast into the Gulf of Mexico. The center of high pressure usually moves across the southeastern states, and the wind along the Texas coast blows from an easterly direction. This air is part of the polar air mass; but, prior to re-entering the Texas coast, it is modified by the warm waters of the Gulf.

The purpose of this paper is to describe the frequency of onshore and offshore winds, and to identify the frequency of the return flow of polar air and of tropical air.

2. AN EXAMPLE

To show the sequence of events, a few days in March 1976 at Corpus Christi, Texas were selected. The dates shown in Figure 1 are 7 to 20 March 1976. The plotted winds are at 0000 and 1200 GMT for each day. The temperature (T), dew-point (T<sub>d</sub>), and equivalent temperature (T<sub>e</sub>) are plotted every 6 hours.

When the wind is offshore (northerly), a cold front probably has passed, and cooling has occurred. As the air from the Gulf moved onshore, the wind was from an eastward direction and was accompanied by an increase of T, T<sub>d</sub>, and T<sub>e</sub>. Variations similar to these continue from September through April along the Texas coast as well as along the coast of the states on the north shore of the Gulf. During the colder months these changes are greater.

3. ONSHORE AND OFFSHORE FLOW

A general knowledge of the area, along with the behavior of T, T<sub>d</sub>, and T<sub>e</sub>, in relation to the wind, as shown in Figure 1, suggests that as the wind direction differs, so do conditions. Equivalent temperature (T<sub>e</sub>) was selected as the parameter used to identify the air mass. Values of T<sub>e</sub> were computed using a program devised by Dr. Henry

Figure 1. The wind (kt), temperature (°C), dew-point (°C), and equivalent temperature (K) variation at Corpus Christi, Texas, 7 to 20 March 1976 at 0000 and 1200 GMT.

Fuelberg.* The program does not have all the refinements proposed by Simpson (1978), but all values of T<sub>e</sub> are computed using the same method so that all have the same (if any) systematic errors. In this paper, however, it is the differences that are more important than the actual T<sub>e</sub> values themselves. (Since the pressures were not really available, a value of 1015 mb was used for all calculations. A change of pressure of 32 mb would make a change of T<sub>e</sub> of about 2°K. The pressure in this area in the winter months is usually > 1000 mb and < 1030 mb so the error in T<sub>e</sub> would

*Now at St. Louis University
be $< 1^\circ$K.) The basic data used were the Local Climatological Data (LCD) published by the Environmental Data Service of the National Oceanic and Atmospheric Administration. The times of 1800 and 0000 GMT (1200 and 1800 LST) were selected because the winds were usually stronger than at nighttime hours. Also, since it was daytime, there were fewer radiation inversions; therefore, the data at these times were more representative of the airmass involved. The months of November, December, January, February, and March were processed for the two times using the years 1965-1976. Three stations - Port Arthur, Corpus Christi, and Brownsville - were selected to represent the Texas Coast.

![Figure 2. Frequency of equivalent temperature at Corpus Christi, Texas for November through March using the 1800 and 0000 GMT temperature and dewpoint for period 1965-1976.](image)

The two values of $T_e$ per day for all five months were placed into an array for each station. A frequency chart was plotted for each station, and Figure 2 is the histogram for Corpus Christi. As can be seen, there is a maximum at 328 K, and a secondary maximum (about 60% of the primary maximum) occurring about $T_e = 295$ K. The multimodal nature of the histogram in Figure 2 (and all the others) suggests that the total frequency distribution is the sum of two or more distributions.

Tables of the wind direction and $T_e$ were compiled for each time for each month. Table 1 is an example of the tables and shows the class intervals used. If the wind speed was less than 2.5 m s$^{-1}$, the observation was not used. Less than one percent of the data were eliminated by this criterion, so this restriction did not make a real difference. From Table 1, the bimodal distribution of $T_e$ is indicated by the totals in the right-hand column. The tendency for the wind to be either from the north or southeast is shown by the bottom row. Combining the two tables to make the monthly total gives a total offshore wind frequency of 370 and an onshore frequency of 364. So, for January at Port Arthur, the onshore winds and the offshore winds blew for about equal amounts of time. For the other months, the percentage of onshore winds increases; also, the more southern stations have a greater frequency of onshore winds. Specifics will be shown later. The average $T_e$ for the onshore winds is 315$^\circ$K, and for the offshore winds, it is 294$^\circ$K. Offshore winds are dryer and colder than the onshore winds.

The values of average $T_e$ and frequency of onshore and offshore winds are shown in Table 2. The temperature $T_e$ of the offshore wind was about 20$^\circ$K colder than the onshore wind. The

**Table 1.** The distribution of the wind direction and equivalent temperatures at Port Arthur, Texas. Only winds of 2.5 m s$^{-1}$ or stronger were used.
### Table 2.
Frequency of occurrence of onshore and offshore winds for selected months and locations. Sum of 1800 and 0000 GMT observations for period 1965-1976. Mean equivalent temperature (\(T_e\) K) for each wind direction. Pressure 1015 mb.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction (degrees)</td>
<td>261-100 101-260</td>
<td>261-100 101-260</td>
<td>261-100 101-260</td>
<td>261-100 101-260</td>
<td>261-100 101-260</td>
</tr>
<tr>
<td>Frequency percent</td>
<td>45 55</td>
<td>50 50</td>
<td>50 50</td>
<td>48 52</td>
<td>38 62</td>
</tr>
<tr>
<td>(T_e) (K) for month by wind direction</td>
<td>303 321</td>
<td>294 314</td>
<td>294 315</td>
<td>296 313</td>
<td>304 321</td>
</tr>
</tbody>
</table>

| Wind direction (degrees) | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 |
| Frequency percent | 44 56 | 47 53 | 50 50 | 44 46 | 23 72 |
| \(T_e\) (K) for month by wind direction | 309 328 | 303 320 | 298 319 | 302 320 | 305 325 |

| Wind direction (degrees) | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 | 261-100 101-260 |
| Frequency percent | 45 55 | 44 56 | 50 50 | 42 58 | 29 71 |
| \(T_e\) (K) for month by wind direction | 314 330 | 306 325 | 303 323 | 306 321 | 310 326 |

Colder months had the larger differences. Also, the colder months had a greater frequency of offshore winds. The cold offshore flow of polar air, and occasionally arctic air, can be identified by both \(T_e\) and wind direction.

### 4. Return Polar Flow vs. Tropical Flow

The problem of separating the tropical air from the return flow of polar air is a difficult task.
The polar air has all blends of modification, and when completely modified over warm water, it becomes maritime tropical air. However, the onshore flow will be examined to see what separation can be made.

There are three general methods of separating the return flow polar air from the tropical air. Two of the three are arbitrary, and both have difficulties. One is defining certain temperatures and dewpoint criteria and then classifying the air to be either polar or tropical. Another method is classifying the airmass according to wind direction. The third method (which is the best) is determining the trajectory of the air parcels. To determine the trajectory requires a knowledge of the wind field over an area for several days. Over the Gulf, these data are not always available; and even then, trajectories are hard to determine. In this paper, the first two methods will be examined. For an example of the trajectory method, see Henry and Thompson (1976, 1978).

### a. Temperature-Dewpoint Criteria

Maritime tropical air is defined as warm and moist. To quantify the words "warm" and "moist" is another problem. Berry et al (1945) list a series of values for airmasses in different seasons. Table 3 lists some values taken from Berry et al with additional calculations of other quantities. The values given are representative of the entire day, so they are a little lower than the daytime temperatures used in this paper.

Shown in Table 4 are some values of $T_e$ and $T_d$.

<table>
<thead>
<tr>
<th>Airmass</th>
<th>Location</th>
<th>$T_e$</th>
<th>$T_d$</th>
<th>$q_f$</th>
<th>$T_e$</th>
<th>$T_d$</th>
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</thead>
<tbody>
<tr>
<td>mT</td>
<td>W</td>
<td>24.7</td>
<td>34.5</td>
<td>1.0</td>
<td>21.3</td>
<td>346</td>
</tr>
<tr>
<td>mT</td>
<td>W</td>
<td>16.3</td>
<td>32.0</td>
<td>11.1</td>
<td>16.0</td>
<td>321</td>
</tr>
<tr>
<td>mT</td>
<td>Pensacola</td>
<td>20.7</td>
<td>33.7</td>
<td>10.3</td>
<td>19.0</td>
<td>322</td>
</tr>
<tr>
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<td>34.1</td>
<td>14.6</td>
<td>21.5</td>
<td>342</td>
</tr>
<tr>
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<td>15.1</td>
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<td>337</td>
</tr>
<tr>
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<td>W</td>
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<td>299</td>
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<td>300</td>
</tr>
<tr>
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<td>286</td>
<td>4.0</td>
<td>1.287</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature-Dewpoint Criteria (K) for selected values of temperature and dewpoint. Pressure 1015 mb.</th>
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<tbody>
<tr>
<td>$T_e$</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>24.7</td>
</tr>
<tr>
<td>16.3</td>
</tr>
<tr>
<td>20.7</td>
</tr>
<tr>
<td>23.2</td>
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<tr>
<td>21.8</td>
</tr>
</tbody>
</table>

**Table 3.** Mean surface conditions for selected air masses and different seasons (W winter, etc.) as given by Berry et al (1945). Dewpoint and equivalent temperatures added.

### b. The Wind Direction Criterion

When a front becomes stationary in the Gulf, the usual wind pattern is: easterly winds occur in the polar air north of the front, and southerly winds occur in the tropical air south of the front. Therefore, the frequency of winds from 070-144° and from 145-220° were determined (with winds less than 2.5 m s$^{-1}$ excluded). The results are shown in Table 5. The results do not appear to be as reasonable as those presented in Table 5. For example, at Port Arthur, the frequency of easterly winds (return flow - polar air) decreases from December to January and continues to decrease during February. This does not seem reasonable, nor does it agree with the results in Table 5. The southerly flow had an average $T_e$ of 315°K while in the easterly flow, $T_e$ was 306°K. The $T_e$ of 315°K is too cold to be tropical air. There must
be some return flow cases mixed with the tropical air, a condition which can be observed on the synoptic map.

The individual values of \( T_e \) for the two wind directions were determined. They are presented in Figure 3. Both curves in Figure 3 have the same range. The easterly wind was colder and had mean \( T_e \) of 313\(^\circ\)K, and in the southerly wind the mean \( T \) was 324\(^\circ\)K. The sea surface temperature along the shore at Corpus Christi is about 16\(^\circ\)C with a strong temperature gradient oriented east-west along the coast. Air arriving from the south could be cooled by the colder water adjacent to the coast. Saturated air at 16\(^\circ\)C has \( T_e = 319\)^\circ\)K. Thus some tropical air may be cooled to below 331\(^\circ\)K.

5. SUMMARY

The offshore flow of air along the Texas Gulf coast in winter can be identified by wind direction, temperature, and dewpoint which may be combined into equivalent temperature. The onshore flow is composed of either modified polar air or maritime tropical air. The distinction between the two air masses is arbitrary, and sometimes a difference does not exist. Probably the easiest method for a quick classification is to call all air with a \( T_e \) less than 331\(^\circ\)K polar, and all air warmer than 331\(^\circ\)K, tropical. The wind may give some guidance; the more southerly winds will be tropical, and the more easterly winds will be return-flow polar air. The percentages of each air mass for each month at each station, as determined by the \( T_e \) criterion, are about the correct values of each air mass as indicated by the synoptic maps in January and February.

ACKNOWLEDGEMENTS

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