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

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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_d), and equivalent temperature (T_e) 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_d, and T_e. 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.

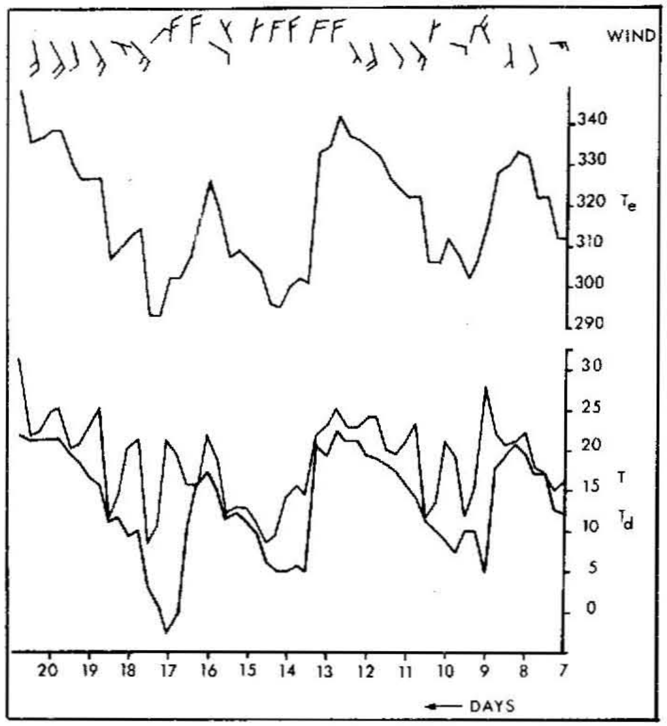

Figure 1. The wind (kt), temperature (°C), dew-point (°C), and equivalent temperature (K) variation at Corpus Christi, Texas, 7 to 20 March 1976 at 0000 and 1200 GMT.

3. ONSHORE AND OFFSHORE FLOW

A general knowledge of the area, along with the behavior of T, T_d, and T_e, in relation to the wind, as shown in Figure 1, suggests that as the wind direction differs, so do conditions. Equivalent temperature (T_e) was selected as the parameter used to identify the air mass. Values of T_e were computed using a program devised by Dr. Henry Fuelberg.* The program does not have all the refinements proposed by Simpson (1978), but all values of T_e 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_e 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_e 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_e would

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be < 1^{o}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 becasue 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.

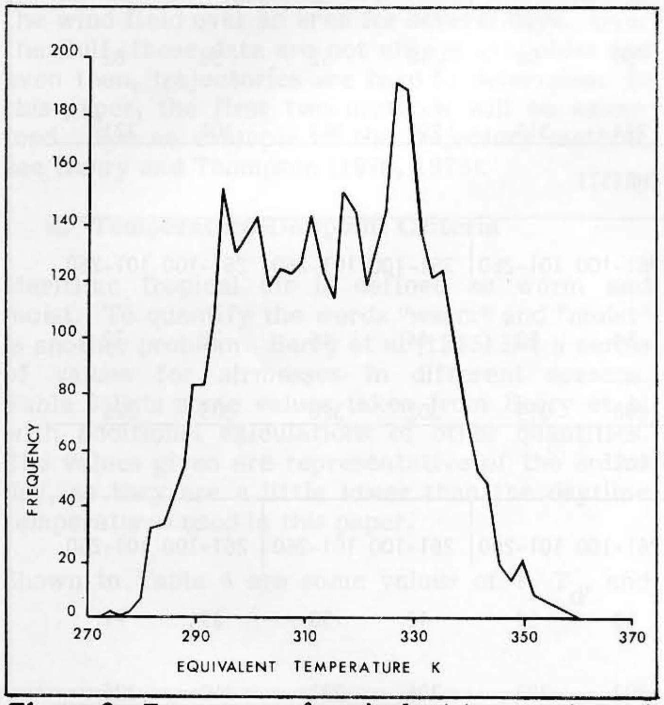

Figure 2. Frequency of equivalent temperature at Corpus Christi, Texas for November through March using the 1800 and 0000 GMT temperature and dewpoint for period 1965-1976.

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},

1800 GMT (1200 LST)

January 1965-1976

Wind Direction (degrees)

	Offshore					Onshore				
T_e (K)	261-300	309-340	341-020	021-060	061-100	101-140	141-180	181-220	221-260	Totals
271-280	1	2	7	4	1					15
281-290	2	8	29	16	9	5	2		2	73
291-300	6	8	13	20	9	7	1	3	3	70
301-310	10	4	12	6	10	14	2	3	3	64
311-320	4		4	2	5	14	8	3	8	48
321-330			1	3	1	14	15	21	5	60
331-340						2	17	12	5	36
341-350										
Totals	23	22	66	51	35	56	45	42	26	366
	Total Offshore 197					Total Onshore 169				

0000 GMT (1800 LST)

January 1965-1976

Wind Direction (degrees)

	Offshore					Onshore				
T_e (K)	261-300	309-340	341-020	021-060	061-100	101-140	141-180	181-220	221-260	Totals
271-280	1	2	9	2						14
281-290	2	7	28	18	5	7	5	4	2	78
291-300	4	11	17	8	9	11	10	5	3	78
301-310	1	6	11	4	10	12	10	8	1	63
311-320	3	1	3	3	6	19	13	8	2	58
321-330			1	1		14	32	19	3	70
331-340							5	2		7
341-350										
Totals	11	27	69	36	30	63	75	46	11	368
	Total Offshore 173					Total Onshore 195				

Table 1. The distribution of the wind direction and equivalent temperatures at Port Arthur, Texas. Only winds of 2.5 ms^{-1} or stronger were used.

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^{o}K, and for the offshore winds, it is 294^{o}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^{o}K colder than the onshore wind. The

Month	Nov.		Dec.		Jan.		Feb.		Mar.	
	off shore	on shore	off shore	on shore	off shore	on shore	off shore	on shore	off shore	on shore
PORT ARTHUR										
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	50	50	50	50	48	52	38	62
$\bar{T}_e$(K) for month by wind direction	303	321	294	314	294	315	296	313	304	321
CORPUS CHRISTI										
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	28	72
$\bar{T}_e$(K) for month by wind direction	309	328	303	320	298	319	302	320	305	325
BROWNSVILLE										
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
$\bar{T}_e$(K) for month by wind direction	314	330	306	325	303	323	306	321	310	326

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 ($\bar{T}_e$ K) for each wind direction. Pressure 1015 mb.

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, T_d, and T_e. Usually maritime tropical air has a dewpoint of 21-24^oC and temperature is higher: but usually less than 34^oC. Air with a dewpoint below 16^oC would not be considered to be mT. After consideration of the values in Tables 3 and 4, 331^oK was selected as the lowest value to T_e that mT air would have.

Airmass	Seasons	Location	T^oC	RH%	q/kg	θe K	T_d ^oC	T_e* K
mT	W	Coco Solo	24.7	88	17.0	345	21.3	346
mT	W	San Antonio	16.3	94	11.1	320	16.0	321
mT	Sp	Pensacola	20.7	91	13.9	331	19.0	332
mT	F	Miami	23.2	92	16.4	341	21.5	342
mT	F	Pensacola	21.8	92	15.1	336	20.5	337
mPk	W	Oklahoma City	8.3	71	5.1	299	4	300
cP	W	Pensacola	4.0	74	4.0	286	1	287

*Pressure 1015.0 mb

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.

T_d °C	T_d °F	T °C 32 / °F 90	27 / 80	24 / 75	21 / 70	18 / 65	16 / 65	4 / 40
24	75	355	350	346				
21	70	348	342	338	335			
18	65	340	334	331	328	325		
16	60	336	330	326	323	320	317	
13	55	332	325	321	318	315	312	
10	50	328	320	317	314	311	308	
4	40	321	314	311	307	304	301	291

Table 4. Some values of the equivalent temperature (K) for selected values of temperature and dewpoint. Pressure 1015 mb.

Using this arbitrary definition, the onshore winds, as shown in Table 1 were separated at 331^oK, and the colder air was identified as return flow (polar) and the warmer as maritime tropical. The frequency of each type of airmass is shown in Table 5. The data in Table 5 show that, as expected, little tropical air invades the northern coast during the winter, but it occurs more frequently in the southern parts of the coast. The lowest values in the month of February indicate the "lag of the season" of the maritime regime.

	Nov.	Dec.	Jan.	Feb.	Mar.
PORT ARTHUR					
Return flow polar	38	41	44	48	47
Tropical	17	9	6	4	15
CORPUS CHRISTI					
Return flow polar	29	40	38	48	47
Tropical	27	13	12	8	25
BROWNSVILLE					
Return flow polar	24	36	36	47	41
Tropical	41	20	14	11	30

Table 5. Frequency of return flow (polar air) vs. tropical air as percent of total winds at Port Arthur, Corpus Christi, and Brownsville (using T_e equal to 331 K as separating criteria). Data: 1800 and 0000 GMT for years 1965-1976.

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^o and from 145-220^o were determined (with winds less than 2.5 ms^{-1} excluded). The results are shown in Table 6. 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^oK while in the easterly flow, T_e was 306^oK. The T_e of 315^oK 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°K, and in the southerly wind the mean T_e was 324°K. The sea surface temperature along the shore at Corpus Christi is about 16°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°C has T_e = 319°K. Thus some tropical air may be cooled to below 331°K.

	Nov.	Dec.	Jan.	Feb.	Mar.
PORT ARTHUR					
Return flow polar	29	31	25	23	29
Tropical	28	25	24	35	36
CORPUS CHRISTI					
Return flow polar	31	26	25	31	39
Tropical	25	27	25	25	32
BROWNSVILLE					
Return flow polar	23	29	18	26	33
Tropical	33	36	32	30	37

Table 6. Frequency of the return flow (polar air) vs. tropical air as percent of total winds at Port Arthur, Corpus Christi, and Brownsville (using wind direction as separating criteria). Data: 1800 and 1200 GMT for years 1965-1976.

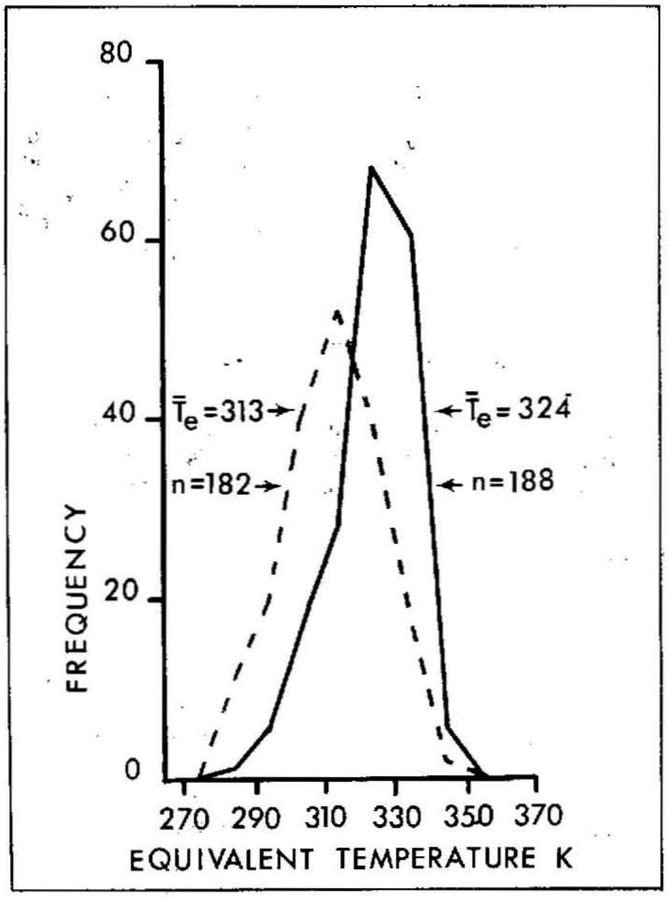

Figure 3. Frequency of T_e for winds from 070-144° (solid line) and from 145-220° (dashed line) for Corpus Christi for January. $\bar{T}_e$ is the mean of the T_e values of the number of cases, n.

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°K polar, and all air warmer than 331°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 airmass as indicated by the synoptic maps in January and February.

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