# Relationship between Monthly Frontal Overrunning and Offshore–Onshore Temperature Differences across the Central Gulf Coast

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ABSTRACT

Under geostrophic and hydrostatic conditions, the Margules equation for the equilibrium slope of a stationary front is applied to study the relationship between monthly frontal overrunning and the temperature difference ($\Delta T$) across the central Gulf Coast. Data employed were 10 years of frontal overrunning statistics, 30 years of onshore temperature and wind records at New Orleans, Louisiana, and 86 years of offshore temperature and wind conditions. Monthly frontal overrunning correlates both meteorologically and statistically with $\Delta T$, as expected. However, the high correlation coefficient of 0.91 was unexpected. The contribution of wind difference across the coastal zone is smaller by far than that of $\Delta T$. The results may therefore be applied for operational planning and to supplement local forecasting of frontal overrunning.

## 1. Introduction

Frontal overrunning occurs frequently when a polar front is more or less stationary along the U.S. Gulf Coast or over the northern Gulf (see, e.g., Muller, 1977). Heavy cloud cover and precipitation are usually associated with this kind of weather system and may cause operational problems, such as disruption of onshore–offshore helicopter flights for offshore oil field workers and supplies because of stronger wind shear and lower visibility than normal. Meteorologically, cyclo- and frontogenesis also may be associated with such a weather system.

Under geostrophic and hydrostatic conditions, the Margules equation for the equilibrium slope of a stationary front is applied to study the relationship between monthly frontal overrunning and the temperature difference across the central Gulf coast. It is hoped that such a relationship may help operational communities to improve their planning and forecasting capabilities.

## 2. Description of frontal overrunning

According to Huschke (1959), overrunning is a condition existing when an air mass is in motion above another air mass of greater density at the surface. This term usually is applied in the case of warm air ascending the surface of a warm front or quasi-stationary front. A quasi-stationary front, commonly called stationary front, is one that is stationary or nearly so. Conventionally a front that is moving at a speed of $\leqslant 5$ Kt (or $\sim 2.5$ m s$^{-1}$) is generally considered to be quasi-stationary. In synoptic chart analysis, a quasi-stationary front is one that has not moved appreciably from its position on the last previous synoptic chart (3 or 6 h before) (Huschke, 1959). A synoptic chart for the frontal overrunning over the Gulf of Mexico is given in Muller (1977).

According to Muller (1977), frontal overrunning occurs frequently when the polar front is more or less stationary along the Gulf Coast or over the northern Gulf. Frequently, waves develop along the front over the western Gulf and then sweep northeastward, bringing heavy clouds and precipitation to southern Louisiana. Table 1 shows some of the characteristics of this weather type. It occurs most frequently in late fall, winter, and spring, when the wave pattern of the circumpolar westerlies often loops southward across North America to the Gulf Coast. Mean monthly precipitation with this weather type was, for example, 38 mm in January during the 1971–74 period in New Orleans and accounted for 31% of the precipitation during that month. Although it contributes $\sim$17% to the precipitation yearly, this weather type accounts for one-fourth to one-half of the monthly precipitation from November through April.

The criteria for selecting frontal overrunning conditions are as follows (R. A. Muller, personal communication, 1980):

1) Fronts located south of New Orleans,
2) A predominantly northerly wind component,
3) Cloud cover 8/10 or greater,
4) All of the above characteristics persist more than 6 h.

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TABLE 1. Annual regime of mean properties for frontal overrunning for New Orleans 1971–74.*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Occurrence (% of hours) | 27 | 16 | 15 | 10 | 8 | 7 | 4 | 4 | 8 | 8 | 23 | 20 | 13 |
| Monthly precipitation (mm) | 38 | 38 | 41 | 30 | 5 | 3 | 10 | 3 | 15 | 13 | 66 | 38 | 300 |
| Monthly precipitation (%) | 31 | 26 | 23 | 25 | 4 | 2 | 8 | 2 | 6 | 16 | 50 | 21 | 17 |
| 0600 CST | | | | | | | | | | | | | |
| Number of cases | 37 | 20 | 24 | 11 | 12 | 10 | 3 | 5 | 11 | 8 | 29 | 23 | |
| Air temperature (°C) | 8.2 | 8.8 | 14.4 | 14.2 | 19.9 | 24.0 | 22.9 | 23.7 | 21.9 | 19.7 | 12.1 | 10.8 | |
| Dew-point temperature (°C) | 4.8 | 4.6 | 11.5 | 12.2 | 16.4 | 20.3 | 20.3 | 21.9 | 19.8 | 18.3 | 9.8 | 9.4 | |
| Relative humidity (%) | 81 | 76 | 79 | 88 | 82 | 80 | 84 | 89 | 88 | 90 | 87 | 91 | |
| Wind direction | 01 | 01 | 02 | 35 | 36 | 01 | 32 | 01 | 01 | 06 | 02 | 02 | |
| Wind speed (m s$^{-1}$) | 5.2 | 5.1 | 5.5 | 4.0 | 4.3 | 1.3 | 2.9 | 1.9 | 3.8 | 3.8 | 4.9 | 4.3 | |
| Cloud cover | 9 | 9 | 10 | 10 | 10 | 9 | 10 | 7 | 8 | 8 | 10 | 9 | |
| 1500 CST | | | | | | | | | | | | | |
| Number of cases | 33 | 17 | 16 | 13 | 10 | 7 | 6 | 6 | 8 | 11 | 29 | 27 | |
| Air temperature (°C) | 11.6 | 12.3 | 16.9 | 21.7 | 23.6 | 29.5 | 27.4 | 27.2 | 27.5 | 23.6 | 14.5 | 13.3 | |
| Dew-point temperature (°C) | 7.0 | 8.1 | 11.1 | 14.2 | 17.7 | 18.8 | 22.1 | 22.4 | 21.4 | 19.7 | 10.3 | 9.8 | |
| Relative humidity (%) | 76 | 66 | 69 | 65 | 68 | 52 | 74 | 75 | 71 | 79 | 77 | 80 | |
| Wind direction | 01 | 35 | 03 | 03 | 01 | 01 | 30 | 34 | 02 | 03 | 01 | 01 | |
| Wind speed (m s$^{-1}$) | 5.3 | 5.2 | 5.5 | 4.4 | 3.7 | 2.6 | 3.9 | 4.3 | 3.9 | 4.5 | 4.8 | 5.2 | |
| Cloud cover | 10 | 9 | 10 | 10 | 9 | 9 | 9 | 10 | 9 | 9 | 10 | 10 | |

* Data source: Muller (1977).

Meteorological characteristics of this weather type are summarized briefly in Table 1, which was taken from Muller (1977).

## 3. Data and analysis

Since frontal overrunning is normally associated with a stationary front, the Margules equation (see, e.g., Hess, 1959, p. 233) may be applied. Assuming that the cooler and denser air is located onshore and warmer and lighter air is offshore, as is usually the case,

$$\tan\theta = \frac{dz}{dy} \approx \frac{f\bar{T}}{g} \times \frac{U_{\text{offshore}} - U_{\text{onshore}}}{T_{\text{offshore}} - T_{\text{onshore}}}, \quad (1)$$

where $\tan\theta$ is the equilibrium slope of the stationary front under geostrophic and hydrostatic conditions, $\bar{T}$ is the mean temperature across the front, $g$ is the gravitational acceleration, $U$ is the wind speed and $T$ is the temperature.

The reason for utilizing Eq. (1) is that it forms a theoretical base for study of the relative importance of the numerator, i.e., the wind difference ($\Delta U$), and the denominator, the temperature difference ($\Delta T$) across the coastal zone with respect to the slope of the front as shown on the left-hand side of Eq. (1). In other words, if the variation of $\Delta U$ is nearly constant or much smaller than that of $\Delta T$, it is obvious that the larger the $\Delta T$, the smaller the frontal slope and therefore the probability of overrunning is greater. Thus, the data were grouped and analyzed according to $\Delta U$ and $\Delta T$, as shown in Eq. (1).

Onshore data were obtained from the National Climatic Center (1977). The station used was New Orleans, Louisiana, an area that has been studied in detail by Muller (1977). Offshore data were obtained from the National Data Buoy Center (1973, p. 120). The area was located between 26 and 27°N, 90 and 91°W. Data concerning monthly frontal overrunning were derived from the Climatic Newsletter, compiled by Muller (1979, 1980), and from personal communication with Muller. They are presented in Fig. 1. Note that different periods (10 years for the frequency analysis, 30 years for the wind and temperature averages at New Orleans, and 86 years for the offshore area) are used because these data covered the longest available periods, according to the data source cited in the reference.

## 4. Results

Fig. 1 shows that the percentage of occurrence of monthly frontal overrunning is controlled predominantly by temperature differences across the coastal zone and to a lesser extent by wind-speed differences. Further correlation between the overrunning percentage and temperature differences is shown in Fig. 2. The correlation coefficient ($r$) is 0.91. Considering only 12-pair (month) data points (Fig. 2), the cor-

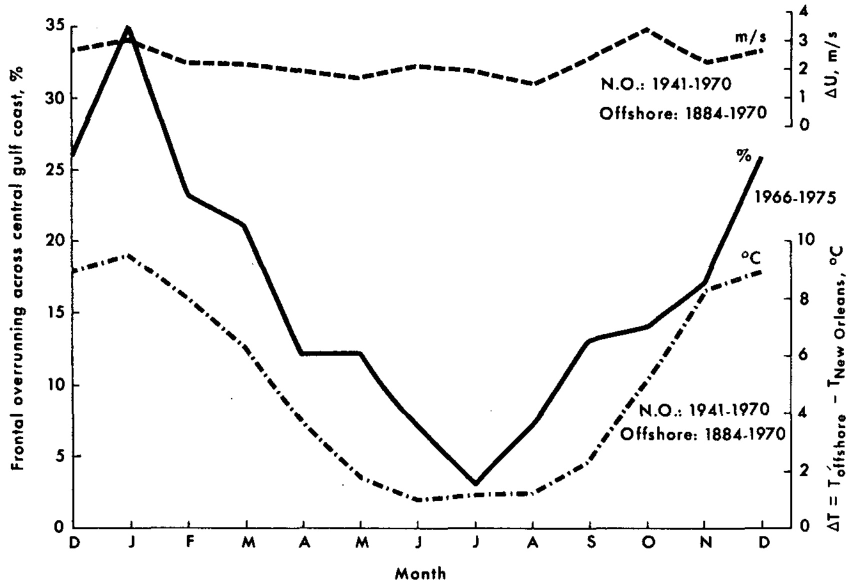


FIG. 1. Monthly variations in air temperature, wind speed and frontal overrunning across the central Gulf Coast.

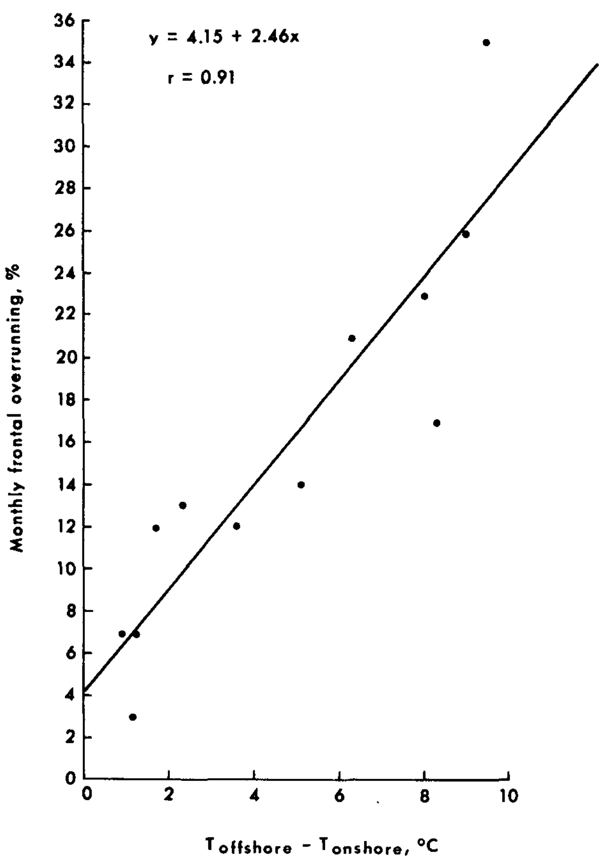


FIG. 2. Relationship between monthly frontal overrunning and offshore–onshore temperature differences across the central Gulf Coast.

relation coefficient is statistically highly significant. Meteorologically speaking, it is understood, and proved as formulated above, that the larger the temperature difference as shown in the denominator in Eq. (1), the smaller the frontal slope and therefore the more chance there is for overrunning to occur. This is shown by the solid curve in Fig. 1, which essentially relates to the slope or the left-hand side of Eq. (1). Since there is very little variation in the wind-speed difference (Fig. 1) from month to month as compared to temperature differences, the numerator in Eq. (1) contributes rather insignificantly to the frontal slope. If this reasoning is accepted, it is possible to use the monthly temperature difference between onshore stations such as New Orleans, and offshore measurements made by meteorological satellites or buoy or rig observations, to forecast the probability of local overrunning. This approach should be used only to supplement forecasts provided by the National Weather Service (see, e.g., Barnes and Heckman, 1980).

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