The German Front Experiment 1987

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Abstract

The German Front Experiment, 1987 (GFE87) is a field experiment using aircraft, radar, surface, and upper-air observations to determine the influence of the European Alps on cold fronts. Measurements are concentrated in the Rhine Valley and in the Alpine foreland south of Munich. The observation period will be between October and December 1987, concurrently with the British and French joint field effort Mesoscale Frontal Dynamics Project (MFDP) and Fronts '87. The background and the setup of GFE are described.

1. Introduction

In recent years, mesoscale meteorology and especially frontal dynamics have received increased attention worldwide. The groups, led by Hobbs (1978) and Browning (1985), have made use of new developments in measurement technology to resolve the structure of fronts in the coastal regions of the eastern Pacific and Atlantic Oceans at the kilometer scale. National research programs, which focus on the interrelation of synoptic and mesoscale circulations during frontal developments, have been conducted in Australia (1979 to 1985; Ryan et al., 1985) or are underway as in the United States (Stormscale Operational and Research Meteorology [STORM] project; Cunning, 1986) or in England and France (Mesoscale Frontal Dynamics Project [MFDP] and Fronts '87; Clough, 1987). These projects mainly address fronts over flat terrain, or fronts in maritime conditions as they reach the coast.

Field experiments to study fronts under the influence of orography started just recently—for example, the probing of an orographically "ducted" type of cold front, the southerly buster, which occurs at the eastern coast of Australia (Coulman et al., 1985). During the Genesis of Atlantic Tropical Lows Experiment (GALE) project in 1986, "backdoor cold fronts" were studied that moved southward along the eastern side of the Appalachians.

The GFE87 constitutes a major experimental activity within a program titled "Fronts and Orography," which is sponsored by the German Science Foundation (DFG) and other German institutions in order to study the impact of the European Alps on cold fronts. The German Front Experiment (GFE) 1987, scheduled to take place during the period 1 October to 18 December 1987, will run parallel to the main experimental effort of the joint British and French projects: MFDP and Fronts '87 (Clough, 1987). Figure 1 depicts the respective experimental areas.

The scientific background for the GFE87 experiment together with hypotheses, and a brief description of the experiment's setup is presented here.

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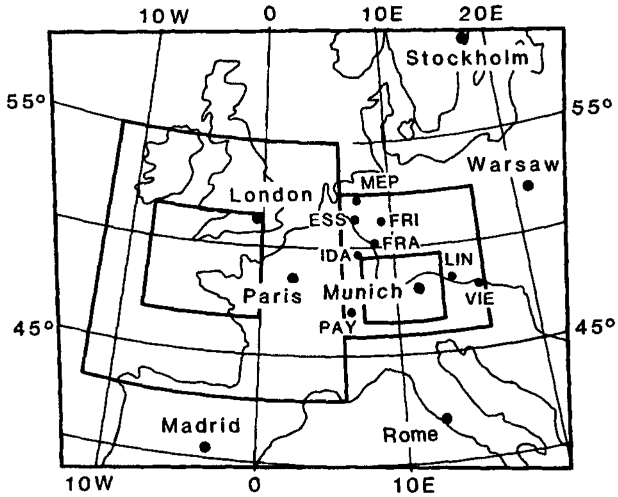

FIG. 1. Geographical location of inner and outer experimental areas for the British and French joint field effort within MFDP and Fronts '87 (left) and the GFE87 (right). Three-letter codes designate aerological stations in the outer area of the GFE87: ESS (Essen, FRG); FRA (Frankfurt, FRG); FRI (Fritzlar, FRG); IDA (Idar-Oberstein, FRG); LIN (Linz, Austria); MEP (Meppen, FRG); PAY (Payerne, Switzerland); VIE (Vienna, Austria).

2. Scientific background

The strong impact of fronts on the weather and climate of the northern Alpine region, and the adjacent foothills of Switzerland, southern Germany, and Austria is well known. For example, fronts cross the Alpine foreland on about 75 days each year (ten-year average), and they cause approximately 50 percent of the annual precipitation (Hoinka, 1985). Weather forecasters in these regions face particular difficulties due to the often irregular behavior of fronts in complex terrain; answers from practitioners to a questionnaire on cold fronts in Alpine regions substantiate these problems (Hoinka and Smith, 1986). Fronts along the borders of the Alps are observed to be deformed or slowed down, but they also can be rapidly intensified or rapidly shifted. The processes that give rise to these behaviors are not well understood.

There are only a few studies that deal with the influence of orography on fronts. Most of them concentrate on leecyclogenesis, particularly in the gulf of Genoa. Several occasions are documented of a front gradually encircling the entire Alps (Steinacker, 1982). Other studies deal with the Australian southerly buster, which is a particularly "abrupt" form of a cold front. Observations indicate that the associated frontal deformation is caused by the interaction with the Australian Alps (Coulman et al., 1985).

The "not well-developed" state of knowledge of the impact of orography on cold fronts is evident from the depth of the discussion in review articles dating from the first half of the present decade. In a summary of a workshop of experts, Hobbs

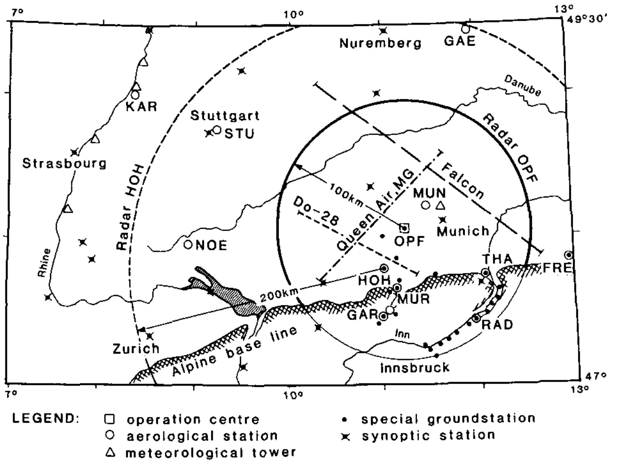

FIG. 2. Geographical distribution of observation systems within the inner area of the GFE87. Three-letter codes designate aerological stations and operations center: FRE (Freilassing, FRG); GAE (Gärmersdorf, FRG); GAR (Garmisch, FRG); HOH (Hohenpeißenberg, FRG); KAR (Karlsruhe, FRG); MUN (Munich, FRG); MUR (Murnau, FRG); NOE (Neuhausen-ob-Eck, FRG); OPF (Oberpfaffenhofen, FRG); RAD (Radfeld, Austria); STU (Stuttgart, FRG); THA (Thalreit, FRG). Wide circles denote the radar ranges of radar at HOH, radar at OPF. Dashed lines stand for flight tracks of the Falcon, Queen Air, do-28, and the motorized gliders (MG).

(1981) states that the influence of topography on the evolution of cyclones is little understood, but does not even mention the orographic influence on fronts and frontal weather. Orlanski (1983) reviews the topic of cold fronts and orography by only presenting some weather charts. Weather observations often show the significant influence that the Alps do exert on fronts; a coordinated effort seems to be well justified to begin to understand these impacts.

3. Scientific objectives

The main purpose of the GFE87 is to collect high-resolution data in order to investigate the structure and the development of orographically influenced cold fronts in the vicinity of the Alps. The central scientific objectives of the experiment are the following:

1) To document a few prominent fronts with different horizontal circulation scales as they cross central Europe;
2) To determine the orographic modification of these fronts; and
3) To explain the physical mechanisms.

As a guide for specific objectives of research concerning the orographic modifications of fronts the following hypotheses, which are to be verified or rejected, have been formulated:

1) Orography intensifies frontogenetic and frontolytic processes;
2) The concept of anafronts and katafronts is valid even under strong orographic influence;
3) The quasi-geostrophic concept of frontogenesis applies under orographic influence;
4) A set of simple parameters (e.g. Froude number) is useful for determining the ratio of flow over the mountains to flow around them;
5) The flow structure in the upper troposphere dominates the orographic influence on low-level frontal propagation;
6) Orography enhances the development of wave disturbances along cold fronts;
7) Trapped density currents occur along the Alpine ridge;
8) Orography modifies the prefrontal low-level jet;
9) Kelvin waves and edge waves occur along the Alps;
10) Cold fronts enter Alpine valleys in a density-current fashion;
11) Orography has a significant impact on precipitation along cold fronts.

The hypotheses clearly refer to different horizontal scales of motion. Accordingly, the experimental setup must be such that features with length scales from meso-α to meso-γ can be resolved (see section 5).

4. Experiment area and time

Figure 1 depicts inner and outer experimental areas for both the British and French field experiment and GFE87. The British and French activities are centered around the channel between Brittany and Cornwall, while the GFE87 field measurements are concentrated in the foreland north of the Alpine baseline, and extend toward northwestern Germany and into Austria.

The duration of the GFE87 is to be concurrent with MFDP and Fronts '87 from 1 October to 18 December 1987. Although the use of aircraft is handicapped by decreasing daylight periods in autumn, the synchronization with the British and French groups offers the unique chance of probing an orographically modified front, which has been measured already in an undisturbed condition over sea. A ten-year climatology (Hoinka, 1985) shows that approximately 15 cold fronts pass Munich during the months October to December. The GFE87 plans to conduct four observation periods during the passage of strong events; each period will last up to 36 hours.

The operational center of the front experiment is located in Oberpfaffenhofen and is operated by the German Aerospace Research Establishment (DFVLR). At this center, forecast information will be collected, and decisions about observing periods, will be made in close contact with the weather service's central office in Offenbach.

Measurements are to be concentrated north of the Alpine baseline and in the valleys of the Loisach River (between Murnau and Garmisch) and the Inn River (between Thalreit and Innsbruck; see Fig. 2). An ideal front, as envisaged, will approach that region from the northwest, and has already been recorded by the rawinsonde network of the outer area (Fig. 1). Two radars will collect three-dimensional data, while different aircraft will execute "cross-sections" at several heights normal and parallel to the front. Special aerological and ground stations at the baseline, in the two valleys, and on some mountains will register the direct contact of fronts with the orography. Another mesoscale experiment will be performed in the upper Rhine Valley around Karlsruhe where tower measurements and surface observations will be performed.

5. Observation systems

The nested definition of the experimental areas is motivated by the necessity to resolve phenomena of different horizontal scales. All observation systems are described from larger to smaller scales, where the parameter Δx denotes a typical sampling distance.

a. Meso-α scale ($\Delta x \sim 10$ *km to 100 km*)

Observations of meso-α–scale phenomena cover the outer area. Data will be obtained from two sources:

1. *Rawinsondes*
The location of aerological stations is given in Figs. 1 and 2. Regular stations of the German weather services (civilian and military) and the Swiss and Austrian services constitute the backbone of the network. Ascents will be made every three hours, or every 90 minutes if possible. Special stations with a sampling frequency up to once every 90 minutes will operate at Karlsruhe, Murnau, Garmisch, Thalreit, Radfeld, and Freilassing. The interpretation of rawinsonde data will be aided by three-dimensional objective analyses on isentropic surfaces (Bleck, 1975).
2. *Satellite data*
Images from the *NOAA-9* and *NOAA-10* satellites on polar orbits are received in Oberpfaffenhofen (channels 1 to 5). These images will aid in the decision as to when to begin an observing period and, later, will serve as a source for interpreting the results. METEOSAT images of Europe and the western Atlantic will be stored in Vienna at intervals of 30 minutes for two channels (visible and infrared).

b. Meso-β scale ($\Delta x \sim 1$ *to 10 km*)

Observations of meso-β–scale phenomena will be restricted to the inner area. The observation systems will comprise:

1. *Meteorological towers in the Rhine Valley*
At four towers (up to 200-m high) the vertical distribution of wind speed and direction, temperature, and humidity will be recorded. Comparisons of the resulting time series over a horizontal distance of 120 km will allow for the distinction between meso-β and meso-γ effects during frontal passages.
2. *Radars*
The DFVLR polarimetric radar scans a cylindrical volume with a 100 km radius and a 10 km height in less than 30 minutes. Doppler winds and liquid-water contents and possibly more-detailed information on hydrometeors can be derived from these data. The weather radar at Hohenpeißenberg and radars from Switzerland and Austria will record the extent and propagation of precipitation patterns.
3. *Surface observations*
Routine data from all snyoptic stations within the inner area will be stored at one-hour intervals. They will be used for the analysis of the temporal evolution of surface frontal positions. These analyses are of key importance in matching the different data taken at various times and locations.

c. Meso-γ scale ($\Delta x \sim 0.1$ *to 1 km*)

Aircraft observations and special surface observations within the inner experimental area will concentrate on meso-γ–scale phenomena. Flight tracks and the locations of stations are given in Fig. 2.

1. *Aircraft*
The fleet of aircraft operated by DFVLR, will include a Falcon jet, the Queen Air and the Do-28, and two motorized gliders (ASK16). The former three can operate under visible and instrumental flight rules, while the gliders are only capable of scanning the prefrontal or postfrontal atmosphere under visible flight rules. All aircraft routinely will record pressure, temperature, and humidity. Additionally, the Falcon is equipped for wind and turbulence measurements and the Do-28 carries "microphysical" sensors. When a front approaches from the northwest, the Falcon and the Do-28 will perform cross-frontal flights at four heights (2135, 2440, 2745, 3050 m MSL) above the baseline shown in Fig. 2. The Queen Air and the motorized gliders will fly similar patterns parallel to the front in the pre- and post-frontal atmosphere.
2. *Special surface observations*
To test for orographically trapped density currents, several sensitive-pressure recording instruments and wind-measurement systems have been installed along a line perpendicular to the Alps between Garching at the northern outskirts of Munich and the Alpine baseline near Garmisch. At the meteorological tower in Garching, fine-resolution time series will be obtained for air and wet-bulb temperatures, pressure, wind velocity, and wind direction at several heights up to 50 m.
At the DFVLR site in Oberpfaffenhofen, a laser Doppler anemometer (LDA) and a sodar will probe the lower atmosphere. LDA will provide hourly horizontal-wind components at eight heights up to 750 m. Sodar will measure discontinuities of sound propagation, which are mainly due to strong vertical temperature gradients; during passages of fronts the heights of thermal contrasts can be deduced (up to 1000 m) in the absence of precipitation. In the surroundings of Garmisch, fine-resolution time series will be established at valley level (750 m), medium level (1750 m), and summit level (2950 m). In cooperation with the university of Innsbruck a series of ground stations will be set up along the Inn River. Together with the aerological station in Radfeld, studies of frontal intrusion into the valley will be possible.

6. Cooperation of institutions

Several institutions will take part in the German Front Experiment 1987. Presently the meteorological university institutes in Berlin, Cologne, Karlsruhe, and Munich are involved. Non-university contributions come from the Institute for Environmental Research of the Fraunhofer Society (in Garmisch) and the Institute of Atmospheric Physics of DFVLR (in Oberpfaffenhofen). The civilian and military German weather services will contribute by increasing observation frequency and by conducting special forecasts that consider systems of interest. International contacts and cooperations exist with the weather services in Austria and Switzerland, with the meteorological institutes in Innsbruck and Zurich, and with the operation centers of MFDP and Fronts '87 in Bracknell and Brest. Additionally, a group from the meteorological institute of Hannover university will join the British and French activity in Brest.

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