cyclogenesis rather than vice versa. But the model still holds in some situations — for example, when mature fronts approach the north-east Atlantic, a wave cyclone of scale 200 km can develop on a cold front, producing an intensification of rainfall over north-west Europe. The reasons for the generation of these waves will be investigated by the new project.

There have been several significant advances since the Norwegian model was formulated. First, the westerly flow in mid-latitudes was shown to be unstable, leading to the periodic growth of the familiar depressions or cyclones. This 'quasi-geostrophic' theory[3,4] predicts rather accurately the horizontal scale and rate of growth of these systems. Although it suggests that in certain regions of the cyclone the conditions are favourable for the formation of fronts, it predicts that it would take an infinite time to produce the observed near-discontinuity. The formation of a front in a short time interval (of the order of one day) was shown to be caused by a non-linear feedback mechanism at the front[5], neglected in the quasi-geostrophic model. This feedback can be described approximately as follows. As air rises just ahead of the front, its rotation about a vertical axis increases essentially to conserve the fluid dynamical analogue of angular momentum. This increase in rotation forces more low-level convergence and hence more ascent. An assumption of this 'semi-geostrophic' model is that the flow remains in a balanced state; that is, the role of high-frequency motions remains merely one of adjustment of the mass and the wind field to each other.

Where, then, are the essential missing links in present-day understanding of the processes responsible for the formation and structure of fronts? The major factor omitted in the semi-geostrophic model is the role of moisture and the consequent clouds and precipitation. Ideas in the past 5 years concerning the basic structure and dynamics of fronts have led to some insight into the production and organization of frontal rainfall[6]. The main questions still to be answered by the new project concern interactions between the processes responsible for rainfall and those ultimately determining the development of the front.

Other aspects that will be investigated include the assumption that frontal regions are one of the most active parts of the atmosphere with respect to the exchange of air (and pollutants) between the stratosphere and the troposphere. The tropopause, the base of the stable stratosphere, is typically at a height of about 10 km above the surface, but it becomes highly distorted locally in frontal zones. Such are the vertical circulations at fronts that the tropopause has been observed to descend to within 3 km of the Earth's surface as a narrow 'intrusion'. Within the intrusion relatively dry and stable stratospheric air is brought far down from its normal location, to be mixed into the tropospheric air. The relative position of the intrusion with the surface front is thought to help to determine the degree of development or suppression of the convection that produces localized areas of heavy frontal rainfall. It is possible to track the position of the intrusion by monitoring tracers such as ozone or water vapour, using satellite or aircraft-borne detectors.

An essential hypothesis of semi-geostrophic theory, that of balanced flow, has recently been questioned — see the *News and Views* article by K. Emanuel[7], who reported suggestions that frontogenesis is halted if the flow becomes unbalanced, that is, if the operation of the non-linear feedback mechanism leading to the sharp front is prevented by the smaller-scale motion at the front. But recent high-resolution observations and modelling work do not seem to support this idea[8,9].

A special field programme is needed because the theoretical models cannot be tested using only the data collected by routine weather-observing networks. These observations of temperature, humidity and winds in the upper air have a horizontal resolution of about 300 km, whereas fronts may be characterized by a scale of only 50–100 km. The weather radar networks currently being developed over much of western Europe can provide rainfall data and an indication of the presence of dynamical features over a wide range of scales from hundreds of kilometres down to less than 10 km, but these observations are not sufficient to define the dynamical and thermodynamical structure. Satellite cloud imagery also provides some information on cloud structure down to small scales but it gives limited quantitative information on atmospheric structure (see Fig. 2).

The planned experiment will focus on the western parts of the English Channel, southern England and northwestern France, where fronts approaching from the west (the dominant direction of movement) will be relatively unaffected by lifting over hills. It is intended that the conventional upper-air observations over the area of the experiment will be enhanced for short periods centred on the passage of fronts.

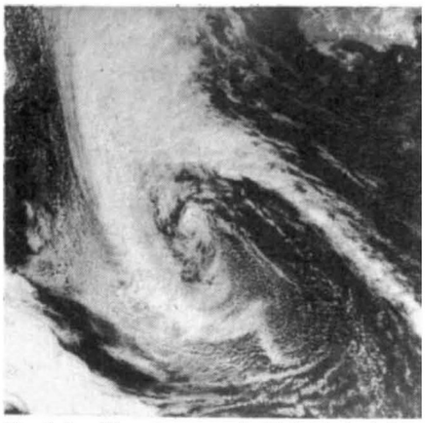

Fig. 2 Satellite photograph (NOAA-9 visible imagery) of the cloud patterns associated with an atmospheric frontal system broadly resembling that modelled in Fig. 1 (courtesy of The University of Dundee).

Extra observing systems will be used to obtain data over the range of scales required. These systems include specially instrumented aircraft such as a Dornier 128 (ref. 10) operated by German scientists to measure winds and turbulence, and a Hercules aircraft, operated by the UK Meteorological Office[11], with the capability of ejecting dropsondes that can make frequent measurement profiles of temperature, humidity and wind. Various kinds of ground-based Doppler radar, operated by French scientists[12], will provide detailed three-dimensional wind fields within areas of rainfall as well as continuous wind profiles within the clear air. Powerful computing facilities will support the running of mesoscale forecast models both in the United Kingdom and France. These models are still in their infancy and it is expected that the data sets obtained in the new project will enable their basic hypotheses and predictions to be tested and improved. □

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Erratum

In the article by Frank Westheimer (*Nature* **319**, 534; 1986) references 8 and 9 should have read: 8. Milstein, S. & Cohen, L.A. *J. Am. chem. Soc.* **94,** 9158 (1972); 9. Modrich, P. & Zabel, D. *J. biol. Chem.* **251,** 5866 (1976). Professor Westheimer's permanent address is: Department of Chemistry, Harvard University, Cambridge, Massachusetts 02138, USA.

Corrigendum

In the article 'The class number problem' by Ian Stewart (29 May p. 474) the example of Fermat's theorem that "every prime of the form $6n+1$ can be written as x^2+3y^2 for integers x and y" should have read: 31 is such a prime, and $31 = 2^2+3.3^2$.