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Defence Services Branch 50th Anniversary
Westward-moving disturbances at Ascension Island

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Defence Services Branch 50th Anniversary. Part I: Historical aspects

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Summary

In January 1939 Met O 6 (then M.O.6) was designated the Meteorological Office Branch responsible for serving the Royal Air Force within the United Kingdom. Thus began an association with Defence work which has lasted 50 years. To mark the occasion this article briefly outlines Meteorological Office activities in support of the Armed Forces from the earliest days of military aviation to the major expansion of air power and services during the Second World War and, more recently, the Falklands Campaign. An accompanying article (Turton and Caughey 1989) reviews the current organization for Defence and the services provided and also assesses likely future trends and requirements.

1. Introduction

Weather has always been a major factor influencing the conduct of military operations. There are many famous instances throughout history of the tactical use of weather by astute military commanders. At Salamis in 480 BC, the Greeks relied upon a freshening southerly sea-breeze to cause ship-handling difficulties amongst larger Persian vessels before attacking them. Julius Caesar was severely hampered by strong winds and high seas in the Channel during his invasion of Britain in 54 BC. In more recent times it is well known that the invasion of Europe in 1944 was crucially dependent upon a suitable 'weather window' (Stagg 1971).

From the few examples quoted above it can be readily appreciated that a military commander must have access to accurate weather information. This requirement becomes particularly important when his forces are outnumbered by their opponents or when resources are limited. The maximum effectiveness must then be extracted from the available resources, and this can often be assisted by intelligent tactical use of weather information and by being aware of the impact of weather on both his own operations and those of his opponent.

As early as 1838, officers of the Royal Engineers on detached duty overseas and consuls serving in foreign ports had been requested to make meteorological observations to build up a climatic database in order to assist the provision of meteorological advice to shipping (both naval and merchant). The Meteorological Office was formed in 1855 as a department within the Board of Trade in response to growing unrest over the unsatisfactory provision of meteorological information to the fishing and merchant fleets. From these earliest days services for Defence formed an important part of the work of the Office. In this article a brief description is given of the growth in services for the military in the early years through to the rapid expansion and development which took place during the Second World War and until the present day.

2. The early years — pre-1939

In the earliest years of the Meteorological Office most work for Defence was concerned with the supply of forecasts and weather information to the Royal Navy, which was still using balloons (Fig. 1) and with attempts to improve the accuracy of artillery fire. There was, however, no satisfactory method of measuring upper-air flow and thus in 1881 experiments were conducted into the detection of upper-air currents by firing light shells vertically. The difficulties of providing a credible forecast service can easily be underestimated in today's world of satellites, fast communications and sophisticated numerical models. All products were generated by laborious manual methods and based on limited data of variable quality.

With the introduction of the first military aircraft in the early part of this century (*circa* 1910) the Meteorological Office appointed (in 1911) J.S. Dines as Officer-in-Charge of a Branch Meteorological Office at the aircraft factory at South Farnborough. He arranged for the provision of weather advice to officers of the Air Battalion and also ran the Upper Air Experimental Station at Pyrton Hill, near Benson. By 1913 the Meteorological Office Forecast Division was routinely supplying (by telegraph) weather reports and forecasts to units of the Royal Flying Corps (Fig. 2), Royal Navy Wing at Eastchurch and the Central Flying School at Upavon amongst others. The Branch

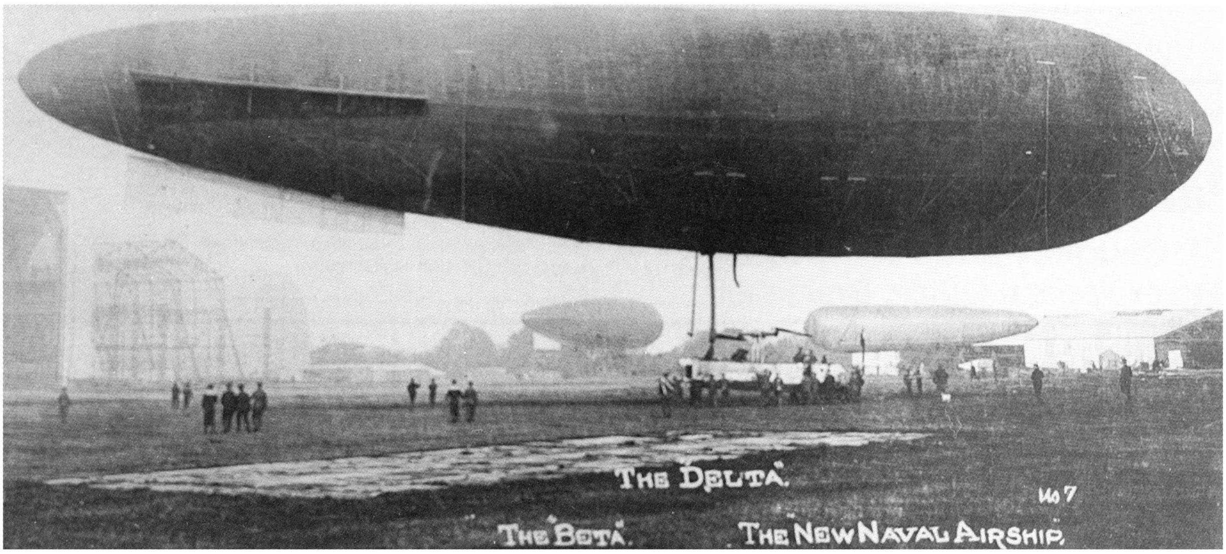

Figure 1. Royal Naval Air Service balloons at Farnborough (*circa* 1912).

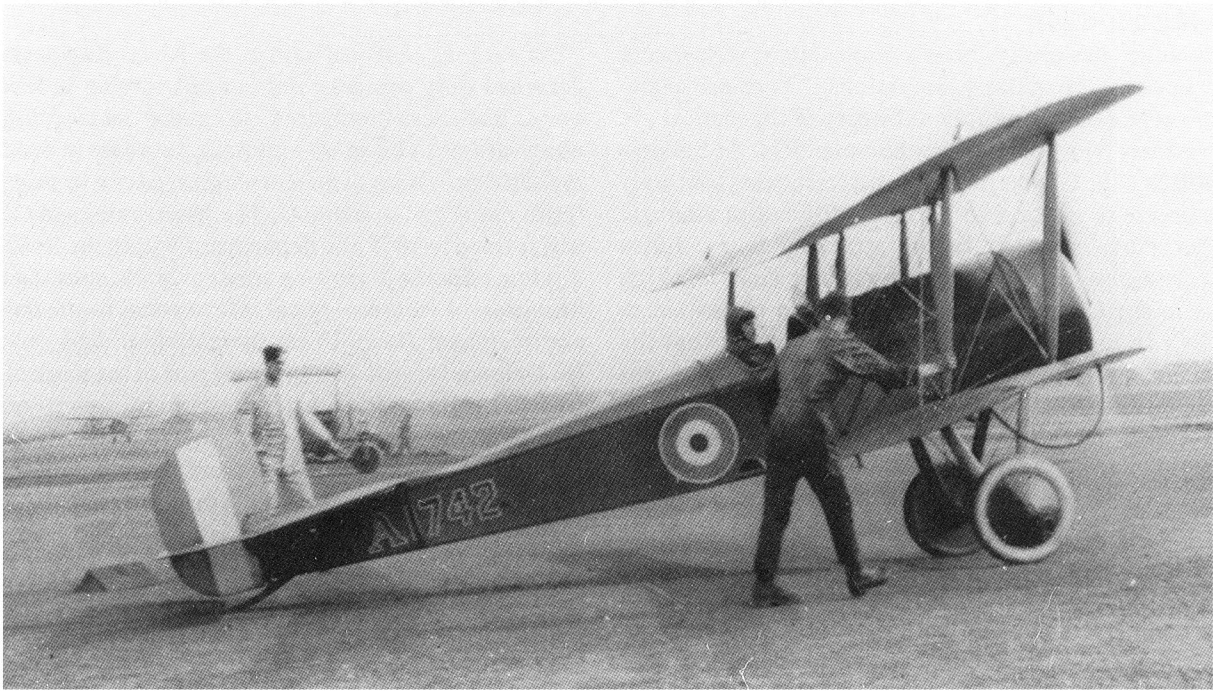

Figure 2. Bristol Scout biplane of the Royal Flying Corps (*circa* 1915).

Photographs by courtesy of RAF Museum, Hendon

Meteorological Office at South Farnborough was made permanent in January 1914 and would thus appear to be the oldest meteorological office serving Defence.

With the approach of the First World War the expansion of services accelerated with reports and forecasts provided for Royal Naval aviation stations, and more frequent night-time observations were introduced to improve the quality of early-morning forecasts. Experiments started with the use of searchlights to monitor cloud-base heights. During the First World War meteorologists were attached to the Royal Artillery for sound ranging and gunnery work and to the Royal Engineers to give advice on chemical warfare matters. The Meteorological Field Service consisted of about 50 officers, mainly from the Meteorological Office, up to the rank of major. Additionally, large numbers of non-commissioned officers (some from the Meteorological Office) and other ranks, drawn from the Royal Navy and the Royal Engineers were trained for service with the various meteorological sections. An example of an actual weather chart from this period which was prepared by E. Gold is shown in Fig. 3.

In 1918 the Royal Air Force was formed from the Royal Flying Corps and although the Meteorological Office initially resisted transfer to the new Air Ministry (Meteorological Office 1919) the move went ahead in 1919. Also in this year the Army Council formally requested further civilian support for artillery work and new offices were opened at Shoeburyness and Larkhill. The growing expertise of the Office in aviation work was recognized with the detachment of forecasters to St Johns, Newfoundland, to forecast for the first successful west-to-east transatlantic flight by Alcock and Brown on 14–15 June 1919.

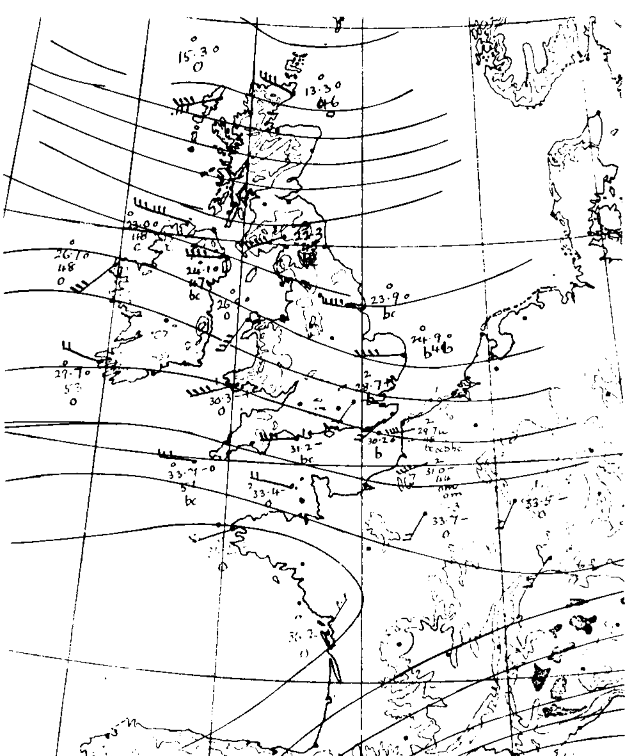

Figure 3. Surface chart for 0100 GMT on 20 November 1917, prior to the Battle of Cambrai.

By 1920 the meteorological organization for Defence consisted of the Distributive Services Division (military and civil aviation), the Army Services Division and the Navy Services Division. All three Divisions received their basic guidance from the Forecast Services Division. Rapid growth continued through the 1920s so that by 1922 the Distributive Services Division (re-titled Aviation Services Division) had ten dependent offices. The Army Services Division had three offices, at Porton, Shoeburyness and Larkhill. Also, 1922 saw the opening of an overseas office at Malta, mainly for Royal Navy and Royal Air Force work. This was followed by eight offices opened in the Middle East during 1926–27 supporting units of the Royal Air Force engaged in pursuance of Trenchard's policy of aerial policing of remote and inhospitable areas. The aircraft in service at this time were mostly biplanes such as the Hawker Hart and Hawker Hind. Further reorganization and expansion took place during the 1930s.

With the approach of the Second World War a rapid expansion of the Armed Forces, particularly the Royal Air Force, took place. In 1936 Bomber, Fighter, Coastal and Training Commands were set up whilst in 1938 Balloon and Maintenance Commands were formed. To meet the growing capabilities of the Royal Air Force, ten new meteorological offices were opened on Royal Air Force airfields in the United Kingdom in 1937 alone. By contrast, in the same year, responsibility for services to the Royal Navy passed from the Meteorological Office to the Directorate of Naval Oceanography and Meteorology. During the period military aircraft increased in sophistication and performance. Also at this time the outstations were supplied with information direct from the then Central Forecast Office but with the approach of war a major organizational change took place which paralleled the changes in the Royal Air Force. The centralized structure was replaced by Command and Group Meteorological Offices, each given control over a number of outstations. Staff from London were devolved outwards to man these new offices and, to mark the event, the Meteorological Office Annual Dinner (Fig. 4) on 27 March 1939, included, after the Loyal Toast, a toast to 'The Decentralized'. Some of the legendary meteorological figures who played an important part in the Second World War can be identified from the photograph.

Prior to this time the Meteorological Office had been organized into a number of rather large Divisions but the increasing demands by the Royal Air Force for more specialized services could not easily be met by them. Smaller, and more manageable, Branches were set up to deal with specific service areas. Hence, late in 1938 the Director of the Meteorological Office signed a letter which authorized the formation of M.O.6 to commence work on 1 January 1939 under the direction of

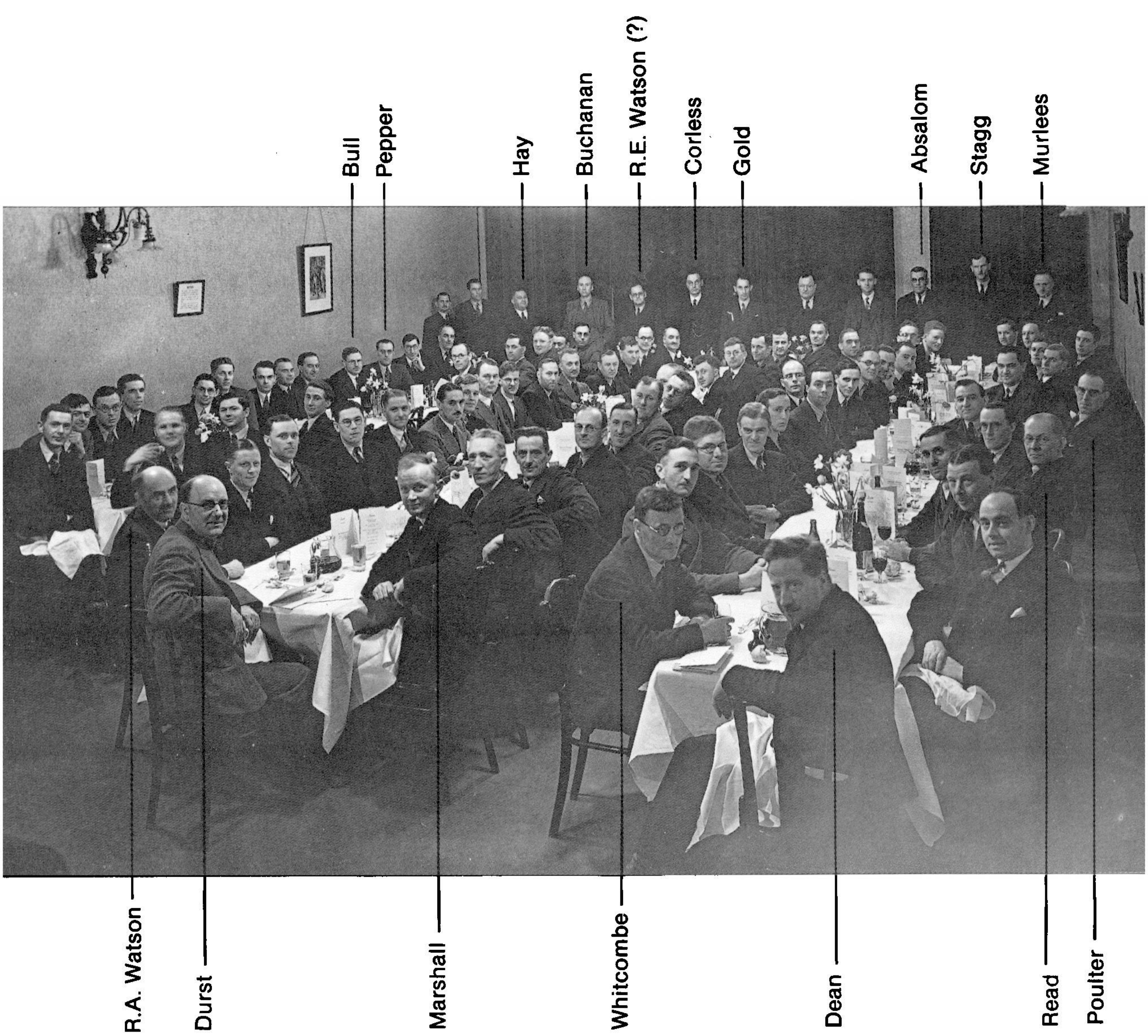

Figure 4. Meteorological Office Annual Dinner on 27 March 1939. *Photograph by courtesy of R.K. Pilsbury*

Mr H.W.L. Absalom. Thus, 1 January 1989 marked the 50th Anniversary of Met O 6 and what is now the Defence Services Branch of the Meteorological Office.

3. The Second World War

In 1939, as a reaction to European political tension, the Armed Forces commenced mobilization. In response to that mobilization the Head of M.O.6 issued, by teleprinter on 26 August 1939, *Emergency Met Instruction No 5*. This was the War Postings List, part of which is reproduced as Fig. 5. It contains some famous names such as Eric Evans and Tom Harrower, both of whom eventually became Assistant Directors of the Defence Services Branch.

At the start of the Second World War M.O.6 was responsible for meeting all Royal Air Force meteorological requirements within the United Kingdom. This period, as one can imagine, was a time of enormous expansion, rapid change and urgent requirements which demanded largely untried products and techniques. By March 1940, and when M.O.6 had been in existence for only 15 months, other Branches (M.O.7 and M.O.8) were already being created to shoulder some of the Royal Air Force burden leaving M.O.6 to deal with RAF Bomber, Coastal and Maintenance Commands. M.O.7 was responsible for RAF Fighter, Training, Balloon and Reserve Commands and M.O.8 for Army Co-operation.

By December 1942 M.O.6 was directly responsible for the meteorological support of Bomber Command, Training Command, Coastal Command (except 15 Group, Liverpool, and 19 Group, Plymouth) and civil aviation in the United Kingdom and north-west Europe (flights to neutral Sweden, Portugal, etc.). M.O.6 was also administratively responsible for the Transferred Training Schools although there is no evidence that staff were sent to them from the United Kingdom. The Transferred Training Schools were Flying Training Schools which had been evacuated to the more peaceful skies of Canada early in the War. The Branch continued

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WAR POSTING
THE FOLLOWING WAR POSTINGS SHOULD TAKE PLACE IMMEDATELY.
 OFFICERS - IN - CHARGE  OF TELEPRINTER STATIONS SHOULD
 ENSURE THAT ALL STAFF AT THEIR AND ASSOCIATED STATIONS ARE
 INFORMED AT ONCE AND JXX MUST REPORT BY TELEPRINTER TONIGHT
 A LIST OF INSTRUCTIONS TO MOVE WHICH HAVE BEEN GIVEN.
 THIS LIST SHOWS THE COMPLETE STAFF AT EACH STATION. THE
 NAME IN BRACKET IS THE HOME STATION OF THE STAFF.
 BOMBER COMMAND ==============
W. H PICK
D W JOHNSTON (SEALAND)
V R COLES
R L SIMS
J S M DAVISON (ABINGDON)
E R THOMAS ( ABINGDON)
D H MILNER (LINTON)
NO 1 GROUP ============
R E WATONS
C WOOD
W L ANDREW
B A COPPING
M E PTIXX PITCHER
S CLARK
NO 2 GROUP ==========
M T SPENCE
E EVANS
W C SWINBANK
C C NEWMAN

                        •

NO 4 GROUP =============
R G VERYARD
H C SHELLARD
A LITTLEWOOD
W A TOMS
C J RYDER (ALDERGROVE)
E C FIELDER
G A COWLING
W D COOPER
NO 5 GROUP ==========
R H MATHEWS
L P SMITH
D G HARLEY

                        •

WEST FREUGH :      T N S HARROWER    B V BISHOP  W D WALLACE
CRANWELL :    P J DRINKWATER W E BILLBOROUGH C H HINKEL
PENRHOS    B J GORST  F M BANCROFT (  SEALAND )
SEALAND    F W WARD  A S SIMPSON   G BUTTLING
TERN HILL  H FORSTER J ANDERSON (  ALDERGROVE )
LOSSIEMOUTH W J CORMACK (  MONTROSE )
NORTH COATES :   L JACOBS  R R ROE
(  TO MOVE WITH SCHOOL )

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Figure 5. Part of the teleprinter signal of the War Postings List sent at 1821 GMT on 25 August 1939*.

* The complete list is incorporated in a copy of this article which is lodged as a pamphlet in the National Meteorological Library, Bracknell.

with this extensive commitment until September 1944 when it was directed to concentrate exclusively on the provision of meteorological support for Bomber Command. This arrangement continued until the end of the War.

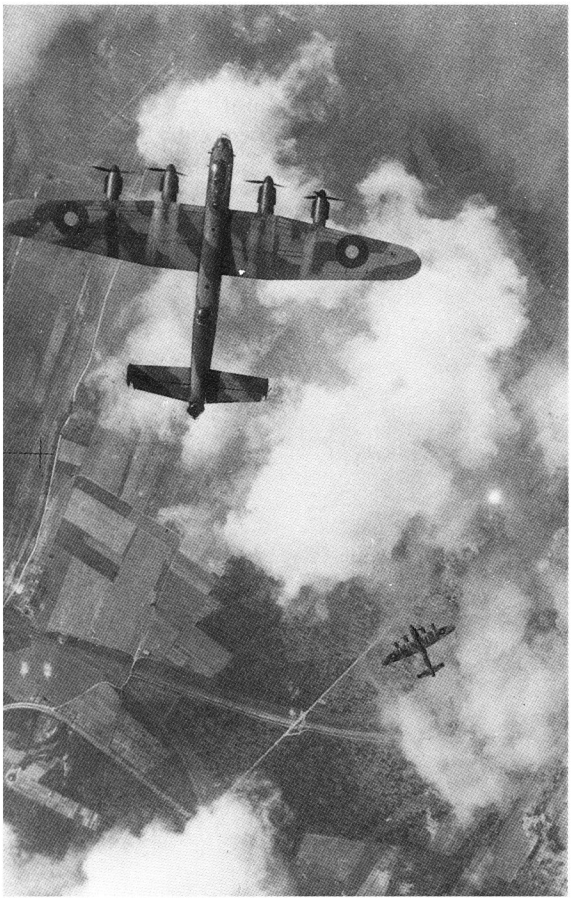
Bomber Command, and subsequently Strike Command into which it was subsumed, has therefore been one of the major customers of Met O 6. During the Second World War M.O.6 maintained a Type 1 Office (equivalent to a Principal Forecasting Office today) at Bomber Command Headquarters at High Wycombe. This Office was in contact with, and provided general guidance to, the other Type 1 Offices at the various Bomber Group Headquarters (1 Group Abingdon, 2 Group Huntingdon, 3 Group Mildenhall, 4 Group York, 5 Group Grantham and 6 Group Norwich). These latter Offices, although designated Type 1, were basically equivalent to a Main Meteorological Office today. The Group Offices, in turn, exchanged forecasts and collected observations by teleprinter within their own network of Bomber airfields.

The techniques of meteorological observing have changed surprisingly little since 1939–45 although the code forms and communications are now far superior and there are more automatic instruments. The wartime observer had no distant-reading thermometers and had to visit the enclosure every hour. He (or, in many cases, she) had no cloud-base recorder but did have a cloud searchlight, and the observation of cloud amounts, types and heights at night was made more difficult by the lack of reflected urban or industrial lighting due to the strict black-out regulations.

It is in the field of forecasting that the major changes have occurred. During the Second World War not only were there no numerical products, no satellite imagery and no weather radar imagery but operational forecasters were just beginning to experiment, in the early part of the War, with thickness fields and Sutcliffe development ideas (Sutcliffe 1947). The upper-air charts were hand-plotted, laboriously hand-drawn and then 'gridded' to produce the final surface prognosis.

At this time the Hurricane and Spitfire had proved their worth as fighters in the Battle of Britain but the Battles, Defiants, Hampdens, Whitleys, Wellingtons and Manchesters of Bomber Command were to be woefully inadequate as the bomber force until the arrival of the Stirlings and Lancasters (Fig. 6) in sufficient numbers later in the War. Coastal Command's Sunderland flying boats were the only really long-range reconnaissance aircraft in the early days until they were joined by Liberators and Catalinas on Lend-Lease from the USA. These, and the Bomber aircraft, carried out long flights with only sketchy forecasts derived from sparse information until regular observations, not only from our own side but also from interceptions of the enemy's data, improved matters.

Fighter aircraft could operate from the surface to 30 000 ft, whilst photo-reconnaissance aircraft were reaching nearly 40 000 ft. The night bombing offensive was



Photograph by courtesy of RAF Museum, Hendon

Figure 6. Avro Lancasters on a Second World War bombing mission (*circa* 1943).

mainly carried out at around the 18 000–24 000 ft level whilst the daylight interdiction raids might be just above the hedge-tops. The long, and often boring, maritime reconnaissance flights were usually flown at around 1500–2000 ft and should be compared with the luxury of the (normally) smooth stratospheric flights of the modern passenger aircraft. These aircraft also made vitally important meteorological observations far out over the Atlantic. The perils of carburettor icing, or of leaving a condensation trail to mark one's position in the sky, were real problems for wartime aviators. It is interesting to note that the 'mintra' line on today's tephigram is still the one originally calculated from the combustion characteristics of a Spitfire engine!

The network of upper-air measurements too, was rudimentary early in the War and it was only when large losses had been suffered by the Bomber Force as a result of scattering due to unforseen or badly forecast jet streams that an Upper Air Forecast Unit was set up at Bomber Command Headquarters. This was to ensure that all the airfields used the same flight winds. It meant that, even if they were in error, at least the bomber streams would stay together and thus be better able to defend themselves. On some occasions when different winds from different stations had been used by navigators of varying abilities the subsequently scattered streams of bombers had suffered enormous losses from enemy night-fighters. The introduction of the Pathfinder Force in 1942, with expert navigators and a single controlling 'Master Bomber', did much to ameliorate the problems and the enormous losses. It is a sobering thought, when one views the relative ease with which a 24-hour numerical wind prognosis can be produced today, to remember just what the Bomber Command upper-air forecaster was trying to produce, by manual methods and with variable data (both in quality and quantity). He alone in the Meteorological Office at that time, knew the target, but everybody knew that if he made an error, the Bomber Force might stray over a heavily defended area with the possible consequence of high losses. There have always been pressures on forecasters but those of the Second World War period were, clearly, quite exceptional.

4. 1945 to the present day

At the end of the War, some 90% of the Meteorological Office staff of 6760 were in uniform. Demobilization started almost immediately as did the reorganization of the various Branch responsibilities. By May 1946 M.O.5 was responsible for the Royal Air Force overseas (including the British Air Force of Occupation in Germany) and M.O.8 dealt with the Army, the Ministry of Supply and Training Command, leaving M.O.6 to deal with the remainder of the Royal Air Force in the United Kingdom. The advent of pure jet fighters (Vampire, Venom, Meteor, Hunter and Swift) with their relatively short endurances increased the emphasis on short-range forecasting. By 1952 M.O.6 was beginning to take on something of today's shape. In that year the last piston-engined front-line bombers, a squadron of Avro Lincolns (descendants of the wartime Lancasters) was detached to Kenya to assist in the control of the Mau Mau uprising. Pure jet aircraft were also making their mark on endurance flying and on 17 December 1953 an English Electric Canberra B Mk2 broke the London–Cape Town record by flying 6010 statute miles in 12 hours 21 minutes at an average speed of 486.6 m.p.h. in celebration of the 50th anniversary of the Wright Brothers' first flight. Forecasting for such distances was a taste of things to come! January 1955 heralded the debut of the first of the long-range 'V' Bombers — the Vickers Valiant — to No. 138 Squadron at Gaydon in Warwickshire.

Further reorganization took place in October 1955 when the responsibility for the supply of all meteorological information to the Army and the Royal Air Force came under the jurisdiction of M.O.6. M.O.5 then became the Communications Branch, while M.O.7 took over responsibility for civil aviation and M.O.8 was tasked with looking after rainfall matters. There were two major military occurrences of note in the mid-1950s. Firstly, in October 1956, the Suez Invasion (Operation Musketeer) took place and some Meteorological Office personnel once again put on Royal Air Force uniforms to advise military commanders, in the field, of the meteorological aspects of operations. The second was the dropping of Britain's 'H-bomb' near Christmas Island (Operation Grapple) in May 1957. At the peak of activity there were some 31 Meteorological Office personnel, under a Principal Scientific Officer, detached to the Pacific. There were also frequent trouble-spots in the 1960s in various parts of the world (Kuwait, Zambia and Borneo) that required some degree of additional meteorological support for the military. As a result of these, and of Suez in 1956, a review of tactical doctrine took place in the Services resulting in an emphasis on mobility and reducing the dependence upon fixed bases. The formation of the Mobile Meteorological Unit (MMU) was a direct consequence of this review. The MMU is a small group of Meteorological Office volunteers commissioned into the Royal Air Force Reserve specifically to provide environmental data and advice in forward areas.

The 1950s and 1960s also saw what was, probably, the peak of M.O.6 world-wide activities when there were staff from the Branch at many locations. These were in Germany, the Mediterranean, the Near East, Africa, the Persian Gulf, the Indian Ocean and the Far East. However, from then onwards Government policy was to progressively concentrate UK forces in support of the North Atlantic Treaty Organization. For example, Habbaniyah (near Baghdad) closed in May 1959 and a Senior Experimental Officer post was established in support of 1 (BR) Corps, Germany in April 1960. Some of the fruits of M.O.5's labours came about in 1962 when all the M.O.6 offices in the United Kingdom were connected to the national facsimile broadcast (NATFAX) for the first time. Confusion had also arisen between the abbreviations for the Meteorological Office and for Military Operations — both 'M.O.'. It was therefore decreed that the Meteorological Office should be shortened to 'Met O' — the current 'Met O 6' title had finally come into existence.

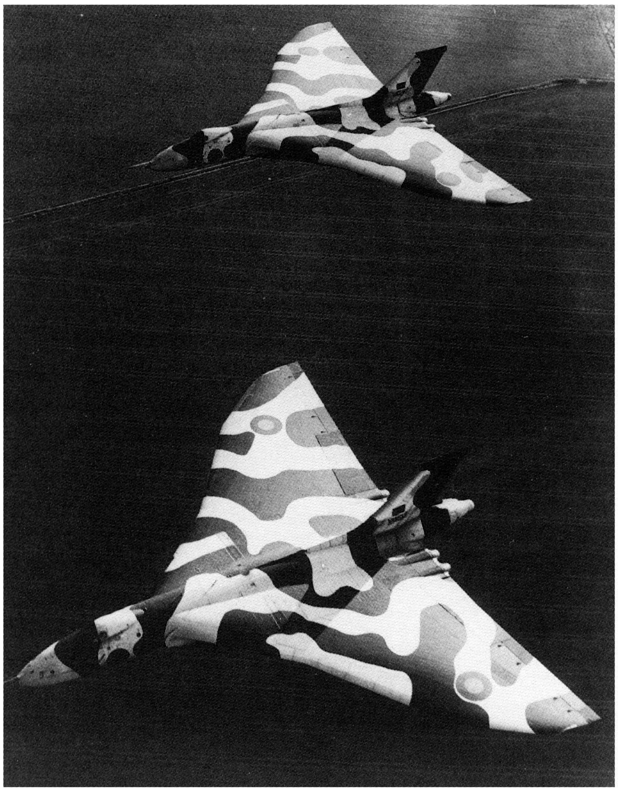
In the late 1960s and early 1970s there were a number of organizational changes as the military withdrawal from east of Suez took place. The meteorological offices in Aden and Borneo were closed in 1967, El Adem in 1970, Sharjah in 1971, Gan in 1976 and Malta in 1978. In 1968 Transport Command became Air Support Command, Bomber and Fighter Commands became Strike Command, and Flying and Technical Training Commands amalgamated to form Training Command. Coastal Command was eventually subsumed into Strike Command in 1969. All these changes had to be mirrored by consequent changes in Met O 6. There were, similarly, a significant number of closures of UK meteorological offices as cuts in the Defence Forces began to bite. For example, Manby was closed in 1974, Abingdon in 1975, West Raynham (for a second time), Andover, Little Rissington, Ternhill and Thorney Island all in 1976, and Pershore and Fairford in 1977.

Simultaneously there were communications developments with the introduction of a number of dedicated military meteorological broadcasts such as the Strike Command facsimile broadcast (STRIFAX), the Strike Command teleprinter meteorological broadcast (STRIMET), the RAF Strike Command Weather Actual System (STCWAS) and the Transport Command meteorological facsimile broadcast (TRANFAX). Numerical weather prediction products of increasing sophistication were being introduced on the Meteorological Office national facsimile programmes at this time.

Also during this period a number of events took place which can be seen as bringing the history of Met O 6 up to the present day. In July 1974 Turkey invaded Cyprus. Quite coincidentally, a detachment of the MMU was on exercise on the island and was able to provide additional support to the ex-patriot staff after the locally employed staff had experienced difficulties in being able to report for duty. A sad occasion took place at Akrotiri in December 1977 when an aircraft crashed on to the meteorological office causing a number of fatalities and serious injuries. However, such was the resilience of the remaining staff (both UK based and locally employed) that a meteorological service was resumed to the military authorities within a few hours.

Easter 1982 saw the start of events in the South Atlantic which culminated in the Falklands Campaign (Operation Corporate) and the subsequent demanding meteorological requirements on the Falkland Island and Ascension Island. Met O 6 was involved within hours of the Argentine invasion. A vast amount of rapid organization was required and provided (Pothecary and Marsh 1983). It is fair to say that the experience at all levels in Met O 6 (and much of the rest of the Meteorological Office) in world-wide meteorological tasks over many years allowed not only a valuable and rapid response to the requirements of the military (Fig. 7) but also the comment that, meteorologically speaking, the South Atlantic was just another place! The MMU played an invaluable role in this operation, setting up makeshift meteorological offices and working in very demanding conditions, both on Ascension Island and, eventually, at Port Stanley Airfield. This expert and immediate response by the Office was recognized by a number of awards and decorations.

For some years the abilities of the meteorologist to assist the military non-aviator had gone largely untapped. Over the years, however, the military appreciation of good environmental support has increased sharply. Warfare, both in the air and on the ground, is becoming daily more scientific and the requests placed before the meteorologists today will require increased skill and ingenuity if they are to be properly met. Several decades ago a major challenge was the accurate forecasting of upper-level winds — today it is the forecasting of very low cloud and visibility and the provision of expert advice concerning the impact of the weather on the operation of electro-optical



Photograph by courtesy of RAF Museum, Hendon

Figure 7. Avro Vulcans of the type used on the Port Stanley Airfield raids in 1982.

systems such as infra-red weapon sights and night-vision goggles. In all cases the meteorologist is working at the extremes of meteorological knowledge and capabilities. Life for the meteorologist serving the military is never dull and does not look as if it ever will be.

Acknowledgement

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Defence Services Branch 50th Anniversary. Part II: Current commitments and the future

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Summary

This paper describes the services currently provided by the Meteorological Office Defence Services Branch to the Armed Forces, Ministry of Defence (Procurement Executive) and other government departments, with emphasis on developments in advice for the use of new technologies employed by the Forces and civil emergency services. The meteorological response to chemical and nuclear emergencies is also discussed.

1. Introduction

In the accompanying article (Caughey and Davies 1989) a brief history of services for the Armed Forces is given. This paper describes those services currently provided by the Meteorological Office Defence Services Branch (Met O 6) for the Armed Forces, Ministry of Defence (Procurement Executive) (MOD(PE)) and other government departments. Support for the Armed Forces is given primarily to the Royal Air Force (RAF) and the Army, although the Royal Navy also relies on the Meteorological Office for basic meteorological information. In recent years there has been an increasing emphasis on the MOD(PE) range activities, in developing advice for the new technology employed by the Forces and in the area of civil emergency planning. These services currently account for about 40% of the total cost of the Meteorological Office and employ around 25% of its manpower.

2. Services for the RAF

Services for the RAF currently involve personnel based at over 50 stations in the United Kingdom, Federal Republic of Germany, the Mediterranean and the South Atlantic. On-site forecasters are established to provide meteorological advice for both operational and non-operational activities. The operational activities include air defence, reconnaissance, air transport and air training tasks for which forecasts, warnings, and information on the actual weather are required. In particular, short-period forecasts of detailed boundary-layer conditions, especially cloud and visibility, are crucial for the increasing volume of low-level flying undertaken by the RAF. This entails regular briefings to aircrew, of which over 200 000 were given during 1988. Forecasts are also provided for other RAF units such as radar stations, weapons ranges and signals units.

The Principal Forecasting Office (PFO) at Headquarters Strike Command (HQSTC) provides technical forecasting advice to most Met O 6 offices. The PFO prepares specialized flight documentation (e.g. low-level significant weather and wind charts) and guidance on broad-scale developments. Recently the PFO was relocated into the newly constructed Primary War Headquarters (PWHQ) at HQSTC. Within the United Kingdom there are three Main Meteorological Offices (MMOs) who, with the PFO, are responsible for the forecasting offices at RAF airfields. At a number of these airfields, facilities known as Wing Operations Centres (WOCs) have been built. Each WOC includes a Meteorological Cell which is manned by Meteorological Office staff during exercises.

Similar facilities also exist for Meteorological Office staff at RAF stations in the Federal Republic of Germany. A Mobile Forecasting Unit (MFU), staffed by Meteorological Office personnel, is also established to support the Harrier Force there (Fig. 1).

Overseas there are MMOs at Gibraltar and in Cyprus, to provide meteorological advice for operations in the Mediterranean. In 1986 a permanent forecasting office (an MMO) was established at RAF Mount Pleasant, Falkland Islands (Fig. 2). This office now provides the meteorological information required by all three Services for operations in the South Atlantic theatre.

The Mobile Meteorological Unit (MMU) forms part of the RAF Tactical Communications Wing and its purpose is to provide forecasts and meteorological advice for exercises in areas where there is no nearby meteorological service. The MMU is manned by volunteers from the Meteorological Office who hold active Civil Conditions Commissions in the RAF Reserve, and may be deployed anywhere in the world in support of the Armed Forces. The MMU was deployed during the Falklands conflict, as described in Caughey and Davies (1989).

On the non-operational side, Met O 6 staff provide basic training in meteorology to RAF personnel at the Flying Training Schools. Some 3700 hours a year are involved in teaching, and the setting and marking of examination papers, for students who may end up as pilots of fast jets, transport aircraft, helicopters, or as navigators or air engineers. The subjects taught cover those relevant to flying, such as the characteristics of air masses, visibility, thunderstorms and icing. Also some training in observational techniques is given to air traffic control staff, who may be required to make observations at stations where there is no meteorological office. The initial training is given at the Meteorological Office College, Shinfield Park followed by practical experience on an operational airfield before the student is awarded a certificate of competence.

3. Services for the Army

The Army Air Corps (AAC), which operates helicopters and light aircraft, also has a requirement for close meteorological support. In particular it has a growing need for advice relating to the use of various weapon systems and night-vision aids. Support for the AAC is provided at its UK airfields and at Detmold in the Federal Republic of Germany, where the Staff Meteorological Officer (SMO) for 1(BR) Corps is established. The SMO deploys with the Corps on field exercises and is supported by an MFU. This involves adopting a somewhat 'outdoor' life-style — most staff agree that Army food has improved over the years!

The Army artillery is also very dependent upon meteorology, and the forecasting office at the Royal School of Artillery (RSA) Larkhill provides ballistic forecasts for the Army training camps in the United Kingdom. Larkhill also produces acoustic forecasts to predict gun noise, so as to help minimize noise disturbance to the community living around the ranges, as discussed more fully later. Since 1986 a forecaster has been based at the Royal Artillery range, Hebrides. This forecaster has a vital job in the planning and execution of trials, both near to the shore and out into the Atlantic. The trials include test firings of ground-to-ground missiles (Fig. 3) and warship training against approaching anti-ship missiles.

4. Services for the Royal Navy

Since 1937 meteorological services for the Royal Navy have been provided by the Directorate of Naval Oceanography and Meteorology (DNOM). Close liaison between Met O 6 and the Royal Navy, in particular between the PFO at HQSTC and the Fleet Weather and Oceanographic Centre (FWOC), Northwood, is maintained. The Royal Navy, however, relies on the Meteorological Office for routine forecast information from the operational numerical models and other more specialized support, e.g. wave charts and surface evaporation-duct forecasts (Turton, Bennetts and Farmer 1988).

Figure 1. RAF Harrier on exercise in Germany.

Figure 2. The Main Meteorological Office at Mount Pleasant Airport, Falkland Islands.

5. Services for MOD(PE)

A number of forecasting offices are situated at MOD trials establishments. The role of these stations is to give the meteorological input needed for decision making relating to the safety and success of trials, and to provide the relevant meteorological data for post-trial analysis. The offices at the Proof and Experimental Establishment (P&EE) ranges at Shoeburyness and Eskmeals provide the meteorological information needed for proof testing of ammunition. Shoeburyness also gives support to the Atomic Weapons Establishment (AWE) explosives testing ground at Foulness. The office at the Royal Aerospace Establishment (RAE), Aberporth provides meteorological advice for the various trials held on the range in Cardigan Bay and at the nearby P&EE range, Pendine. Here some specialized facilities are needed, for example accurate monitoring of rainfall is required in trials of weapon fuse mechanisms (Hewston and Sweet 1989). The office at RSA Larkhill, in addition to giving meteorological assistance to the Army, also provides support to RAE Larkhill and the Chemical Defence Establishment (CDE), Porton for its various trials. Full upper-air sounding facilities are established at the Eskmeals, Shoeburyness, Aberporth and Larkhill offices.

One of the tasks of these stations is the provision of acoustic forecasts to predict the levels of noise, resulting from explosions or gunfire, around the ranges (Turton, Bennetts and Nazer 1988). This is important to minimize public disturbance and to avoid complaints, whilst

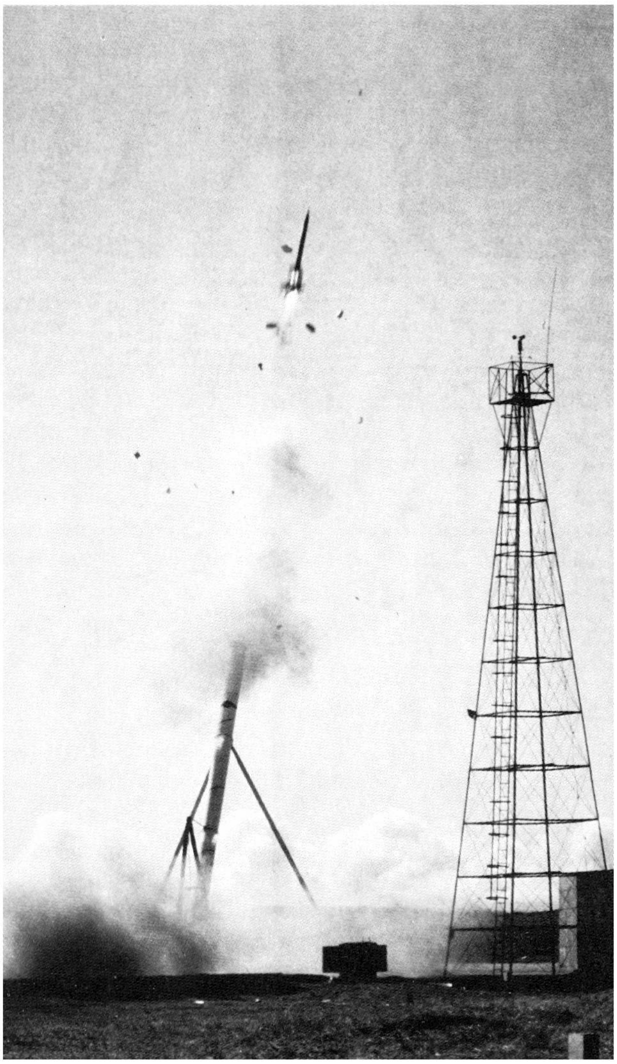


Figure 3. Rocket firing in trials at the Royal Artillery range, Hebrides.

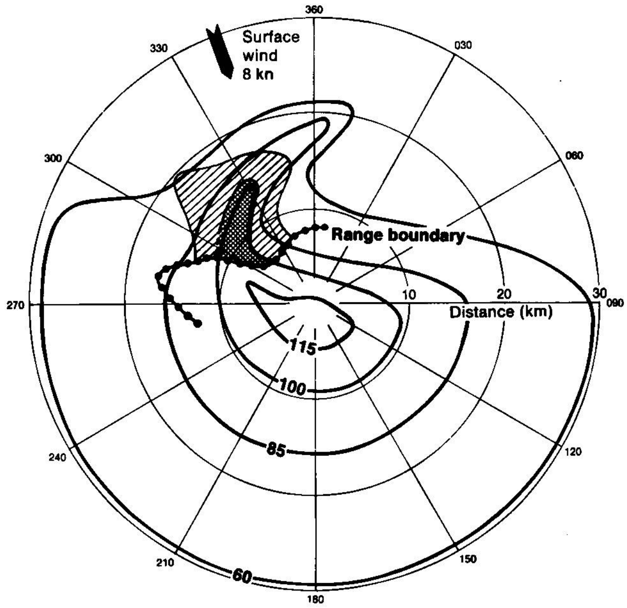


Figure 4. Acoustic forecast showing predicted noise levels in decibels. The shaded and hatched regions indicate areas where the gunfire was reported to be 'very loud' and 'loud' respectively.

maximizing the use of the range facilities. Fig. 4 shows an example of an acoustic forecast for gun noise from Larkhill. An unusual feature in this case was that the reports of noise occurred in an upwind direction from the guns and were due to focusing rather than the more usual downwind noise enhancement. However, the relation between the predicted and reported sound patterns is seen to be reasonably good in the upwind direction.

Met O 6 is currently collaborating with the University of Salford and CDE Porton in a research programme sponsored by MOD(PE) Safety Services Organization to develop improved methods for predicting impulsive noise. The programme includes the development of a new acoustic model, based on more realistic acoustic and meteorological theory, for operational use at the ranges. Also, instrumentation for remote monitoring of the noise levels around the ranges is being developed. Attention is also turning to the prediction of sound from continuous noise sources such as aircraft.

6. Services for the United Kingdom Warning and Monitoring Organization (UKWMO)

The UKWMO, which is part of the Home Office, is responsible for providing warning of an air attack and monitoring any subsequent nuclear fall-out. Knowledge of the meteorology is essential for the prediction of the spread and intensity of the fall-out. The Meteorological Office provides forecasters for the UKWMO sector controls, each of which has responsibility for a particular region. Regular exercises to test the network are held, for which Met O 6 provides meteorological data from which a fall-out pattern is determined.

7. Emergency planning

The Defence Services Branch is responsible for formulating the meteorological response to nuclear and chemical emergencies. These are considered according to the location of the incident and the nature of the hazardous material involved.

7.1 Nuclear accidents within the United Kingdom

The Department of Energy is responsible for co-ordinating the national response to a civil nuclear accident within the United Kingdom. The Ministry of Defence is responsible for co-ordinating the response to any nuclear accident which may occur at a Defence establishment or base, or to nuclear powered warships or to Defence nuclear weapons, reactor or materials whilst being transported. The spread of debris from such an accident is highly dependent on the meteorological conditions and Met O 6 was responsible for developing the procedures known as PACRAM (Procedures And Communications in the event of a release of RadioActive Material) to ensure that the appropriate meteorological advice is available. Each nuclear establishment is associated with a designated Meteorological Office, where arrangements for the provision of advice on weather conditions and the movement and dispersal of released material have been agreed. This involves an initial forecast by the designated Meteorological Office of those factors (e.g. wind speed, mixed-layer depth and stability) which are used to define the initial spread of the plume. The Central Forecasting Office at Bracknell would then be notified and a forecast forward trajectory computed from the fine-mesh model.

7.2 Nuclear accidents overseas

Following the reactor accident at Chernobyl, the Office has played a significant role in the development of the Government's National Response Plan (NRP) which arranges for departments and agencies to react to international nuclear incidents. Her Majesty's Inspectorate of Pollution (HMIP), part of the Department of the Environment which has responsibility for co-ordinating the response to an overseas accident, has equipped 46 Meteorological Office observing sites with gamma radiation monitors (HMIP 1989). This network (Fig. 5) is known as the Radioactive Incident Monitoring NETwork (RIMNET). The gamma radiation measurements are made by Office staff and passed hourly to Bracknell where they are automatically sorted and re-transmitted to HMIP's computer databases in London and Lancaster.

In order to ensure rapid notification of any future accident internationally the World Meteorological Organization (WMO) and the International Atomic Energy Authority have agreed that the WMO Global Telecommunication System may be used to provide initial warning and information. This message would be received at Bracknell, HMIP alerted and the NRP activated if appropriate. A Technical Co-ordination Centre staffed by officials from various government departments, including the National Radiological Protection Board and the Meteorological Office, would assess the effects of the incident on the United Kingdom, assist ministers and keep the public and media informed.

The Meteorological Office would also run a nuclear accident response model which would draw on meteorological and radiological data to predict the movement of radioactive material across the United Kingdom and the pattern of both wet and dry deposition. This model includes those factors that were found to be significant following the Chernobyl accident (Smith 1988).

7.3 Chemical emergency

Hazardous volatile chemicals are stored at thousands of sites throughout the country. In the event of a spillage or leak, meteorological factors will play a large part in determining the area affected. Detailed procedures

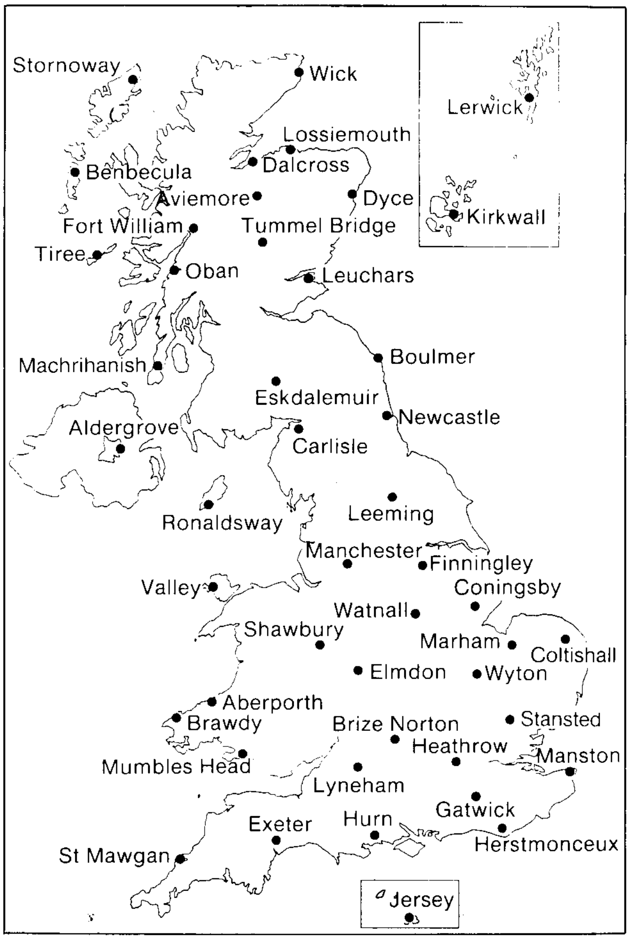


Figure 5. Locations of the RIMNET sites.

(CHEMET — CHEmical METeorology) have been developed to help cope with the handling of chemical accidents. Each MMO (and some Weather Centres) is allocated an area of the United Kingdom; if the office receives notification that an accident has occurred within this area then the CHEMET procedure is activated. The essence of the CHEMET service is the provision of timely advice on the dispersal and track of released chemicals to the Police, who will pass this information to the other emergency services (Fire and Ambulance) so that appropriate action can be taken.

8. North Atlantic Treaty Organization (NATO)

Met O 6 staff represent the United Kingdom on the NATO Military Committee Meteorology Group (MCMG) and the Supreme Headquarters of the Allied Powers in Europe (SHAPE) Meteorological Committee. These groups co-ordinate the provision of meteorological support to NATO forces in peacetime and develop appropriate contingency arrangements for crisis situations. The needs of major NATO commanders are considered against the facilities and services provided by the nations of the Alliance. The MCMG also provides a forum for those concerned with the provision of meteorological support to the Armed Forces to meet and discuss advances in techniques and facilities developed by any one nation, leading to benefits for others.

In addition, Met O 6 represents the United Kingdom on the NATO Armies Armaments Group (NAAG) Independent Special Working Group No. 3) (ISWG. 3) on Meteorology, the Target Area Meteorology Instrumentation and Analysis (TAMIA) and the Civil Defence Committee (CDC) groups. ISWG. 3 is concerned with the provision of meteorological data to the Alliance Armies for a wide range of uses, e.g. to provide ballistic messages for the use of artillery in the field. The TAMIA group is addressing the problems of the acquisition, processing and use of meteorological data from the battlefield. These data will be required for use in new Tactical Decision Aids (TDAs) which are being introduced. The CDC is involved with defining the areas at risk from the use of chemical (or biological) weapons.

9. New developments

In recent years the Defence Services forecaster has had access to a wider variety of products as improvements in the forecast models and communication systems have been made. A new communication and information system — the Weather Information System (WIS) — which will provide high-speed digital links to forecasting offices is under development. A simplified form of this facility, known as Outstation Display System (ODS), where stations are being equipped with microcomputers to give them rapid access to processed data and forecast products is under way (Cluley and Hills 1988). This is enabling them to provide more accurate and detailed weather information and forecasts. The improvement in the meteorological service, due to more rapid access to observational data, has been very significant indeed. To date, some 18 offices have had ODS installed; it is expected that all offices should have the full WIS by the early 1990s.

As this new equipment is being introduced the Defence Services forecasters are at last getting timely access to basic meteorological data, of a range and quality that enables them to carry out the demanding and time-critical local forecasting task. However, as new technology and equipment are being introduced by the Services, the role of the forecaster is expanding. No longer are they required just to give information on the general weather characteristics, but increasingly they are being asked to provide advice on how weather will affect the new technology being employed by the Armed Forces. These new developments demand that meteorologists have a good understanding of the new technology and that they combine this knowledge with accurate meteorological forecasts and data to provide the most useful advice to Force Commanders.

In particular, the effects of weather on radar propagation, electro-optic systems and the movement of troops and equipment are areas currently being studied. Forecasters are being asked to provide detailed assessments of the impact of meteorological conditions on the performance of these systems and the movement of resources. To assist them, computer programs and models are being tested and developed. These TDAs provide the military commanders with the specific information which is needed to assist in tactical decision-making.

For example, electro-optic imaging and ranging devices are becoming more widely used as they overcome many of the problems associated with night flying, especially in poor weather conditions. Both the RAF and the AAC use night-vision goggles (NVGs) for night flying, but these devices will only work when the ambient light exceeds a certain threshold level. The light incident at the top of the atmosphere depends upon the positions of the sun and moon relative to the earth. However, the amount of light that actually reaches the surface is reduced because of scattering and absorption by aerosol and water particles in the atmosphere, in particular by cloud and rain. The ambient light-level also includes a contribution due to 'cultural' lighting; this is light from towns and cities which is reflected back by clouds. Fig. 6 shows an example of how the light levels during a night can be affected by the passage of a frontal system when the light level remains low until the frontal cloud cleared by 0100, after which time the light increased. Consequently the use of NVGs would have been, at best, marginal until this time.

Thermal-imaging devices are also being fitted to many aircraft; although these also provide 'night vision' they do not have an all-weather capability. Cloud and rain can obscure the image and reduce the range at which targets can be detected to an unacceptable limit. Computer models which combine the characteristics of such sights with the relevant weather information and then predict the performance parameters for such devices (e.g. target detection and lock-on ranges) are currently being evaluated by Met O 6.

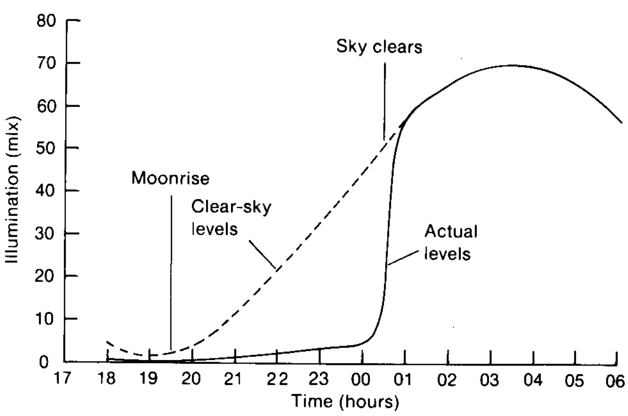


Figure 6. An example of the way in which the passage of a frontal system can alter the natural illumination levels at night; for comparison the clear-sky levels are also shown. A moon phase of 75% was specified with moonrise at 1930 and a front clearing by 0100.

Radars are employed on a wide variety of tasks and platforms by the Armed Forces. It is well known that the coverage of radar systems can be severely affected by the atmospheric conditions (Turton, Bennetts and Farmer 1988). Under some circumstances part of the radar beam can be trapped, forming a duct with coverage out to exceptionally long range. However, above the duct there is a region where less radar energy penetrates, such that targets may escape detection. This is illustrated in Fig. 7, where a radar coverage in ducting conditions is shown alongside the 'normal' coverage of the same radar; here the differences are due solely to the atmospheric conditions.

Weather also affects the mobility of Army ground forces. Previously, assessments of manoeuvrability were made manually by Force Commanders using all the information available to them. This is a formidable task and is well suited to computerized techniques. Detailed databases for evaluating the military options are being developed in the Army TERAS (TERrain Analysis System) programme. TERAS will consist of a detailed topographic database and climate information, together with environmental and battlefield data. The environmental data, which includes meteorology, is a vital part of TERAS and will require the forecaster to regularly update and amend the meteorological input. It is expected that the various TDAs as discussed above will eventually be incorporated into TERAS.

10. Concluding remarks

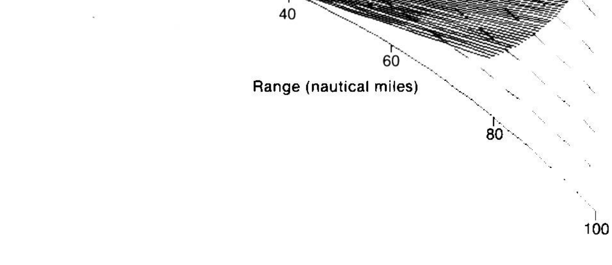
Part I (Caughey and Davies 1989) of this article gave a description of the way in which services for Defence have developed in the Meteorological Office, since its inception to the present day. Major developments in these services occurred in order to meet the demands of the military during the two World Wars. Just before the Second World War, the Defence Services Branch was formed. Since then, the Branch has been involved in providing meteorological assistance to the Forces world-wide.

This paper has discussed the wide range of services currently provided for the Armed Forces, MOD and other government departments. In recent years advances in computer technology have changed the face of operational meteorology. As forecast models have become ever more sophisticated with higher resolutions, the accuracy of their predictions has improved significantly. High-speed communications (e.g. WIS) are already giving outstation forecasters rapid access to a wider array of observational data and forecast products, enabling them to give much more accurate meteorological advice.

Another development that is likely to prove important in forecasting is the development of artificial intelligence and expert systems. The latter are computer programs which can apply reasoning and judgement to a particular problem. Already, pilot projects on expert systems for predicting precipitation and thunderstorms are under way at the Meteorological Office (Conway 1989). Such techniques are potentially of great benefit to the Defence Services forecaster.

New technology is also being employed by the Services (e.g. electro-optic imaging and ranging devices). However, the performance of such equipment is weather sensitive, and the forecaster is being asked to give advice on the use of this equipment. Computer programs and models (TDAs) are being introduced to assist the forecaster in this area. Another key area of current concern is the acquisition of meteorological information from data-sparse or battlefield areas, required as input to the meteorological forecast models, the TDAs and TERAS.

Given improved observational data, better numerical forecast models, forecasting algorithms and artificial



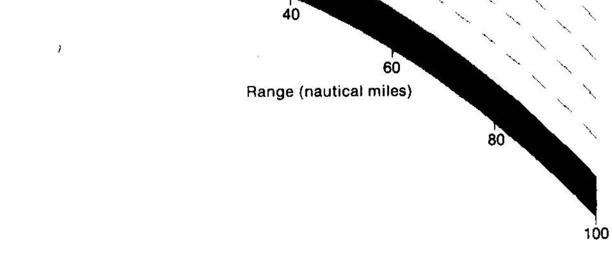


Figure 7. Radar coverage diagrams in (a) normal and (b) ducting conditions, where a surface-based duct 1000 ft deep was specified with the radar at 750 ft height.

intelligence systems, the demanding local forecasting task of the Defence Services forecaster will become more tractable. However, there is an increasingly important need for advice relating to the impact of meteorology on military equipment and operations. The preparation and dissemination of this type of advice will demand the adoption of new skills and computer techniques. The most effective presentation of these new products to the user will require excellent links between Meteorological Office (WIS) and military automatic data processing facilities. As far as one can judge, the outstation meteorologist will continue to have an expanding and important role in support of the Forces, assisting them to conduct vital operations and exercises in the years ahead.

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Westward-moving disturbances in the South Atlantic coinciding with heavy rainfall events at Ascension Island

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Summary

Easterly atmospheric waves in the northern hemisphere have been well documented but much less is known about similar features in the southern hemisphere. A study of upper-wind time cross-sections maintained at Ascension Island during the early part of 1986 suggests that features with similar characteristics to easterly waves affected the island, probably triggering several heavy rainfalls which occurred during that time. Some evidence is produced that the 15-level model of the Meteorological Office is able to reproduce these disturbances.

1. Introduction

Ascension Island is situated at 8° S, 14° W in the South Atlantic (Fig. 1). It is a small isolated island, 1450 km from Africa, over 1600 km from South America and 1100 km north-west of its nearest neighbour and mother colony, the island of St Helena. In recent years Ascension Island has played an important role as a staging post between the United Kingdom and the Falkland Islands.

All available literature about the climate of Ascension Island (see Hodges (1985) for a comprehensive list of references) and the experience of Meteorological Office staff based on the island (Brenchley 1986) indicates that Ascension Island has a very pleasant tropical climate. It is predominantely dry, apart from (in some years) spells of 'drizzly' showers, sometimes several such spells occurring over a period of a month or more. However, in some years there are infrequent rainstorms occurring mostly in March and April. Table I shows some of the heavy rainfalls reported on Ascension Island. It should

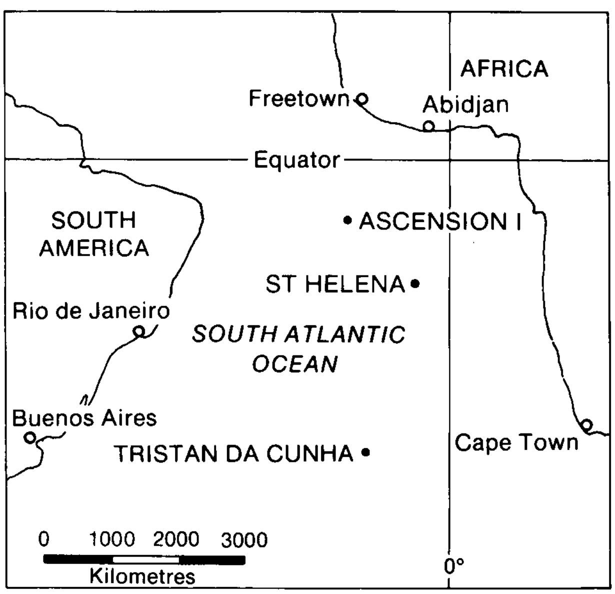

Figure 1. Location of Ascension Island.

Table I. Heavy rainfall reported on Ascension Island

Year	Month (if known)	Event
1831	—	'Dampier's tank*' damaged by heavy rains.
1859	June	'Great rains', 9 inches (229 mm) in a day with damage to roads and crops. 20 inches (508 mm) fell in June and 108 inches (2743 mm) were recorded in the year at Green Mountain (see Farm Site Fig. 2).
1864	April	Very heavy rainfall, thunder and lightning.
1887	April	Great damage to roads. Yearly total 56 inches (1422 mm) at Green Mountain.
1896	—	'Unusual thunderstorm'; Capt. Napier's Japanese steward 'revived by a good brandy' after being struck down when the overhead telephone wire was hit by lightning.
1899	May	Heavy rainfall.
1909	April	Heavy rainfall.
1924	April	'Freak' rains; 5.62 inches (143 mm) fell at Georgetown during the month. Waist-high grass over low ground and a plague of insects.
1934	April	Torrential rains, an 'astonishing cloudburst' —209.6 mm fell in 12 hours 29/30 April at Georgetown.
1950	March	75 mm of rain during the month at Georgetown.
1963	March	'Great rainstorm'; 96.5 mm fell on 29 March at Georgetown. Extensive damage to roads, cemetery flooded, landslides.
1964	April	95 mm of rain during the month at Georgetown.
1974	March	90 mm of rain fell during the month at Georgetown.
1978	—	Annual rainfall total at Two Boats village 48.5 inches (1232 mm).
1979	April	80 mm of rain fell during the month at the Pan Am site at Wideawake Airfield.
1984	March	317 mm of rain during the month at the RAF base at Wideawake Airfield. Runway closed on 4 March due to erosion and boulders; road damage.
1985	April	538 mm of rain measured at Traveller's Hill during the month; 145 mm fell at the RAF base in one day on 7 April.
1986	April	67 mm of rain fell at Traveller's Hill on 9 April; 'spectacular lightning display'.

* Two large stone water tanks built by the famous buccaneer, explorer and Admiralty hydrographer, William Dampier, on the lower slopes of Green Mountain can still be seen today.

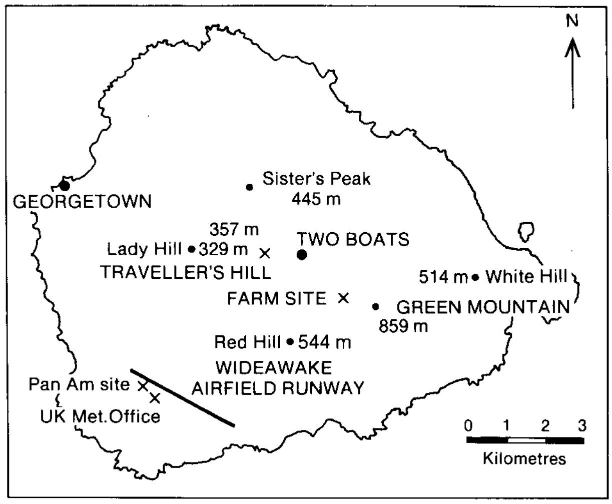

Figure 2. Ascension Island, including the locations of places mentioned in the text.

be noted that records are probably only reasonably reliable since 1924 when regular readings were started at Georgetown (Fig. 2). Not every heavy rainfall event is included in the Table, only those of interest.

In 1984, 1985 and 1986 heavy rainfall occurred on the island — some falls heavy enough to cause flooding, soil erosion and road damage. These events also had serious consequences for aviation. For example, George (1984) described how the pilot of an RAF Hercules aircraft returning from the Falklands had great difficulty in landing his aircraft at Ascension Island (Wideawake) airfield owing to a severe storm on 4 March 1984. The pilot was considering 'ditching' when the navigator spotted the rock-strewn runway through a gap in the cloud; the pilot managed to land the aircraft safely with only 30 minutes of fuel remaining. In another incident, on 15 October 1985, a Boeing 747 was diverted to Abidjan, Ivory Coast, because of low stratus associated with frequent showers. These, and several other less serious incidents, warranted an investigation into the possible causes of such poor weather.

It is important to point out that, as the local investigation proceeded, it became clear that the lighter 'drizzly' showers are usually associated with very shallow low-level instability (cloud tops often limited to 5000 feet under the inversion of the sub-tropical high). Patchy low stratus beneath these showers is a significant hazard to aircraft on descent into Ascension, but is an entirely different forecasting problem. This occurs with the greatest frequency from August through to January with much year-to-year variation and some problem-free years. Here consideration is given to the possible causes of the heavier, deeper instability-controlled showers which occur mainly during March and April and may be associated with easterly waves.

2. Investigation

The heavy rainfall events in 1984, 1985 and 1986 appeared to be linked with the passage of westward-moving disturbances rather than local or diurnal convective development (Johnson 1978, Ross 1985). Studies of the satellite picture sequences leading up to the heavy rainfall events revealed that the origin of the disturbances was Africa, probably over the Congo basin in Central Africa. This suggests similarities with the easterly waves in the North Atlantic which originate over West Africa (Albignat and Reed 1980). The subsequent investigation had three objectives:

(a) To devise some forecasting rules for predicting heavy rainfall on Ascension Island in the South Atlantic.

(b) To establish whether such heavy falls are associated with easterly waves.

(c) To examine examples of 15-level model analyses to see whether they are capable of reproducing the changing wind-field profiles associated with the passage of these disturbances.

Before describing the results it is important to state the limitations of the investigation:

(a) Little success has been achieved locally at Ascension Island in using temperature and humidity soundings to confirm or predict changes in instability. Vertical motion can only be inferred from known changes in upper-wind profiles derived from once-daily soundings (American radiosonde data are available for 1200 GMT only, Monday–Friday inclusive).

(b) Cross-sections of the variation of upper winds with time were only available for the period 20 January–30 April 1986 but model wind-field analyses (including vertical profiles) were available, for the 3 years 1984–86.

(c) To enable direct comparison between radar winds and model wind fields, the investigation has been deliberately limited to horizontal wind components.

(d) Although Ascension Island covers an area of only approximately 35 square miles, it is quite common for downpours to affect one part of the island whilst other regions remain virtually dry. The heavy falls noted in Table I were recorded at a number of different sites (Fig. 2).

3. An example of the changing upper-wind profiles

In order to study temporal changes in vertical wind-structure at isolated locations where radar-wind information is available, vertical wind-profiles can be plotted as time cross-sections. This method was introduced at Ascension Island early in 1986 and produced some interesting results. In January 1986, a heavy rainfall event occurred after a marked change in vertical wind-profile (Fig. 3). On 21 January the strongest winds were at a level of 5 km — north-easterly 25 kn. By 24 January, as indicated by the 25 kn isotach on the profile, the zone of strongest winds had lowered to between 3 and 4 km and veered* to easterly. During the weekend 25–26 January, no upper-air data were available but by Monday 27 January it was evident that the lower-level winds had veered to around 140° (from the usual 110°) and the strong middle-level easterlies had ceased. Over 40 mm of rain was recorded at Traveller's Hill (Fig. 2) on 28 January and by 29 January the winds between levels of 5 and 6 km had backed to 070° whilst at low-levels they had returned to their normal direction and rainfall had ceased. Some kind of 'disturbance' can

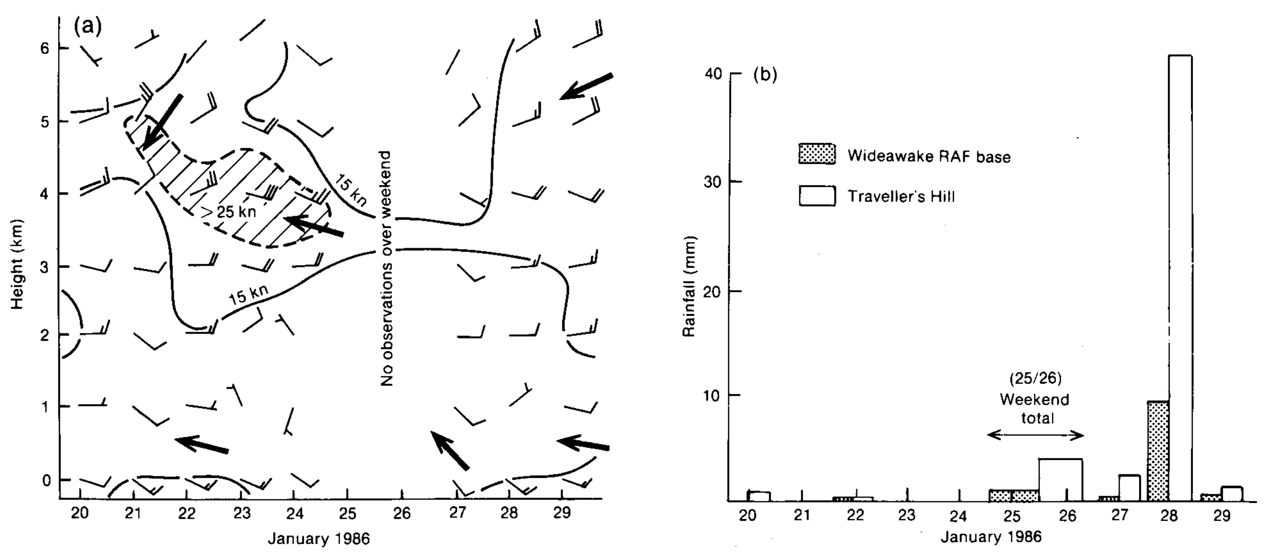

Figure 3. (a) Variation of upper-air winds with time, and isotachs added for clarity, for the period 20–29 January 1986 at Ascension Island. The wind arrows indicate horizontal wind speed and direction as in conventional weather symbol plotting. The bold arrows also indicate horizontal wind direction but, only approximately, speed; they are shown to emphasize the significant changes of wind, and (b) daily rainfall at two sites for the same period.

*In this article veering indicates the wind direction increasing in azimuth (measured N–E–S–W) and vice versa for backing. Among forecasters the opposite convention is used in the southern hemisphere.

readily be seen to have passed westwards over Ascension Island.

4. The onset and duration of heavy rain

A careful analysis of a number of case studies from early 1986 indicated that the structure of the disturbances associated with heavy rain was similar to that of the easterly waves found in the North Atlantic. Fig. 4 shows schematically the low-level structure of the disturbances associated with heavy rainfall found in the southern hemisphere, and their vertical structure is given in Fig. 5. In most cases, small pressure changes (of the order 0.5 to 1.0 mb) occurred over and above the normal diurnal variation. Generally, veering surface winds were associated with pressure falls and backing winds with pressure rises. Vertical motion could be inferred from cloud behaviour near to the rainfall event: ascent, by towering cumulus or cumulonimbus clouds, increasing both in height and extent prior to the falls, and subsidence by clouds decaying rapidly after the trough or wave. In each case studied the trough or wave axis exhibited a slope with height, a similar finding to that of

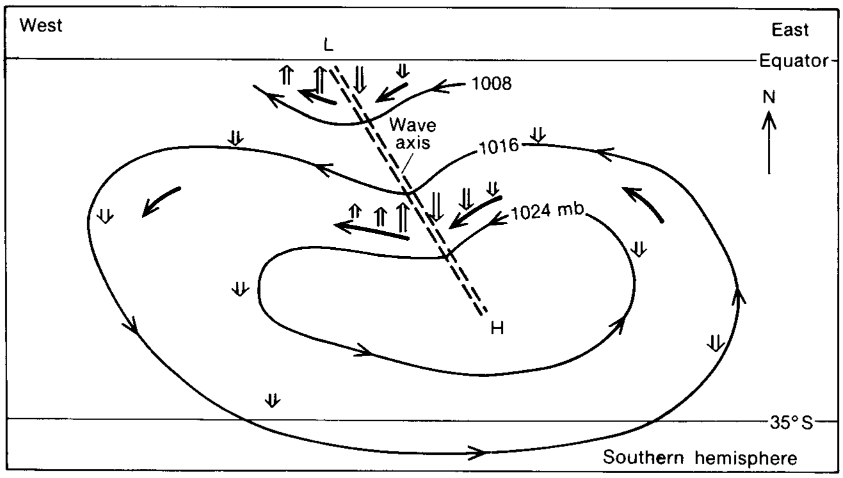

Figure 4. Schematic diagram of an easterly wave in the southern hemisphere (horizontal structure at low levels). The bold arrows are as in Fig. 3 and the hollow arrows give some indication of the direction and magnitude of the associated vertical motion.

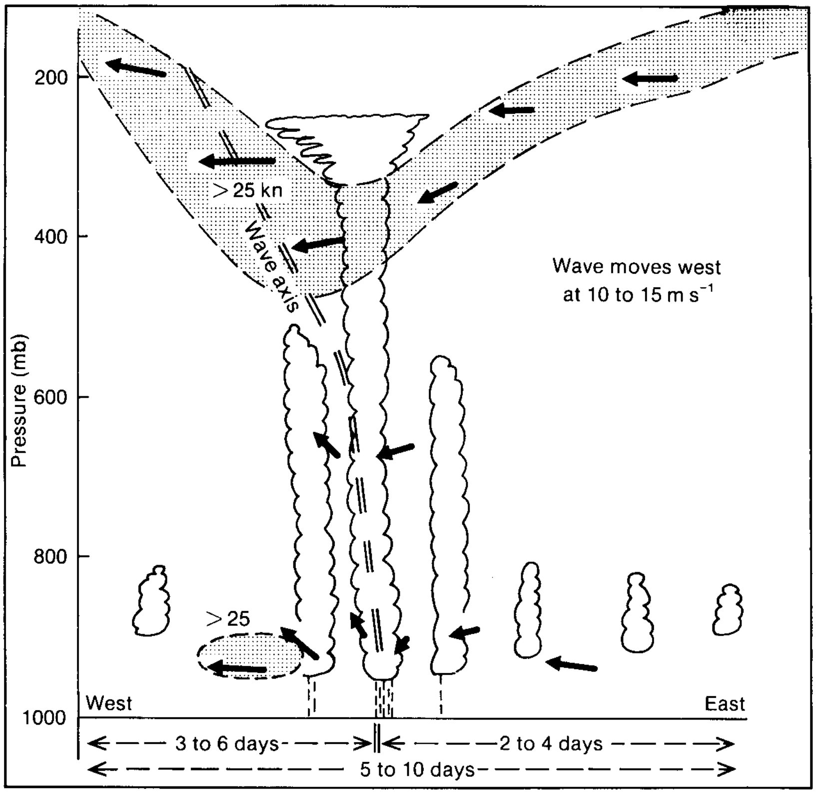

Figure 5. Schematic diagram of an easterly wave in the tropical southern hemisphere (vertical structure). The symbols are as in Figs 3 and 4. The horizontal scale shows the approximate time that the wave takes to travel across the longitude of Ascension Island.

Albignat and Reed (1980) who concluded that easterly waves sometimes show a tilt characteristic of baroclinic disturbances.

In late summer (January and early February) in the vicinity of Ascension Island, as a result of strong westerlies aloft, marked wind shear usually exists at around 10 km, thus limiting vertical stability and allowing isolated moderate to heavy showers rather than violent downpours. However, as autumn approaches and upper winds reverse to easterlies, deep convective clouds can form with cloud tops reaching 12–15 km. It is possible that it is easterly waves which trigger the storms over Ascension Island. A study of the lengths of showery periods during 1986 revealed a strong link between these and the rapidity of onset and lowering of the zone of stronger easterly winds aloft. Prior to short showery periods of only a day or so, the onset of strengthening easterlies was quick (only apparent 1 or 2 days before the showers). However, when the easterlies strengthened to 25–35 kn over a greater depth, say 4–5 km, and over a period of 3 or 4 days, then an unsettled period lasting 3 or 4 days followed. The cessation of showery activity coincided with the return of middle-level easterly wind speeds to the normal values of 10–15 kn.

Fig. 6 shows an example of a time cross-section of the upper winds associated with heavy rainfall. The marked 'slopes' indicated by the 25 kn isotach indicate the lowering and subsequent retreat of the stronger easterlies very well. This example confirms the lowering of stronger upper easterly winds prior to a period of heavy rainfall and shows evidence of one or more weather troughs at low level (rainfall was not continuous during this period but comprised heavy, showery bursts). In this instance, lowering of the 25 kn isotach took 3–4 days with the subsequent showery periods lasting also 3–4 days.

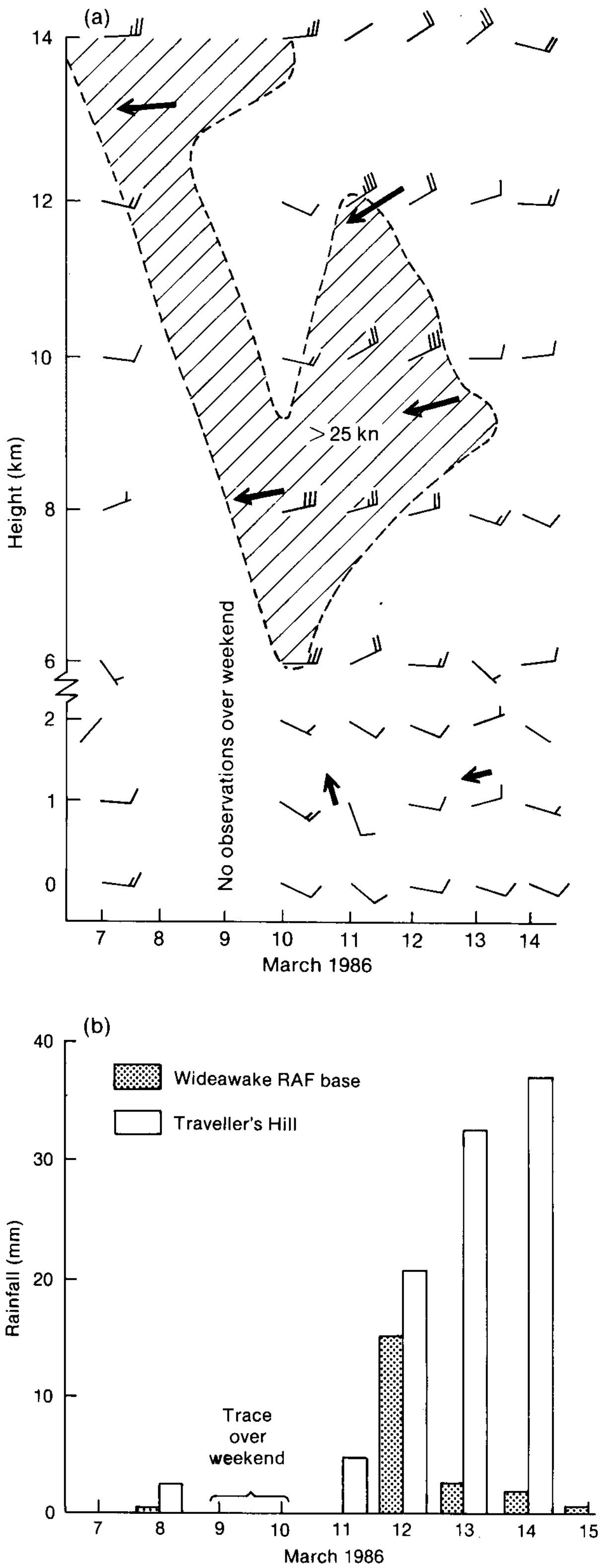

Figure 6. As Fig. 3 but for 7–14 March 1986.

5. Analyses from a global model

Divergence and convergence clearly play an important role in controlling the degree of vertical motion involved. Preliminary study of the operational analyses from the global model of the Meteorological Office (Bell and Dickinson 1987) has shown that the model is capable of indicating middle-level (700–500 mb about 3.5–5.5 km height) divergence and low-level (900–850 mb about 1.5 km height) convergence coinciding with rainfall events. An example for 4 March 1986, has been chosen because (unlike the one given in section 4 covering 7–14 March) a short period of heavy rain only was involved with no interruption of radiosonde data, enabling comparison of measured with model winds. On this particular occasion, changes in low-level winds were minimal but at 6–7 km (500–400 mb) both measured wind profile (Fig. 7) and spatial model wind-field (available for 500 mb, about 5.5 km height — Fig. 8) indicate divergence near, or moving away west from Ascension.

A month or so later, during the night of 9/10 April 1986, spectacular displays of lightning, thunderstorms and torrential rain occurred over Ascension Island. The event was different from those observed previously, in that it was preceded by an increase in upper westerly winds at heights between 9 and 15 km. The ability of the model to depict very accurately the changes in wind

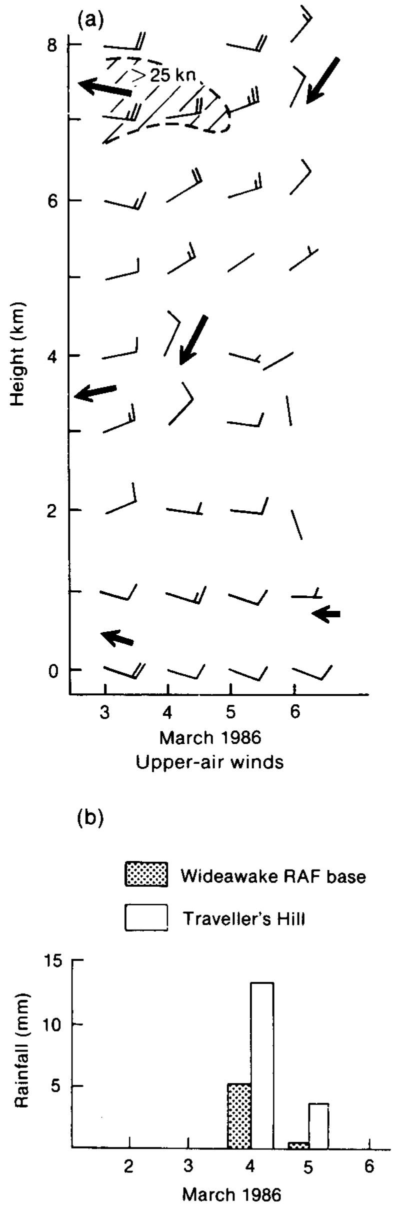

Figure 7. As for Fig. 3 but for 3–6 March 1986.

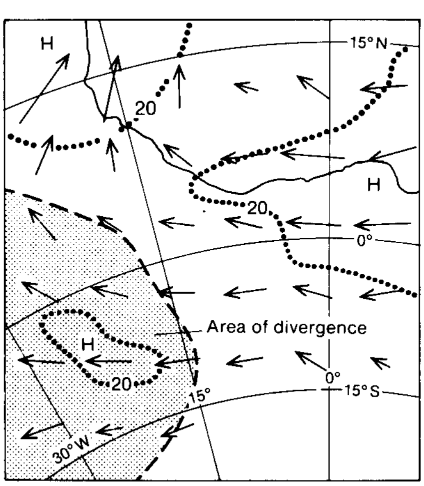

Figure 8. 500 mb horizontal wind-field for 00 GMT 3 March 1986 showing area of divergence west of Ascension Island and the 20 kn isotachs.

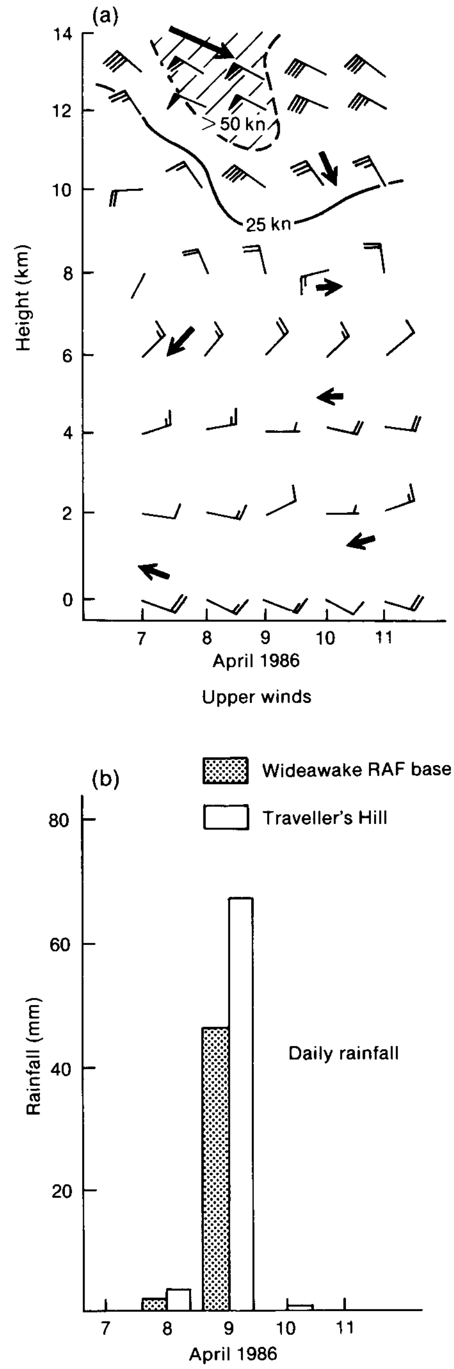

Figure 9. As for Fig. 3 but for 7–11 April 1986.

profile which took place is demonstrated by comparison of Figs 9 and 10.

6. Concluding remarks

A careful study of satellite picture sequences, linked with use of a time cross-section of upper-wind profile changes, can give useful indications of the approach of disturbances likely to give severe weather at Ascension Island. The following are forecast rules based on the study:

(a) On the vertical time cross-section, look for lowering of strong wind zones, combined with a veering of middle-level winds. Initially, strong

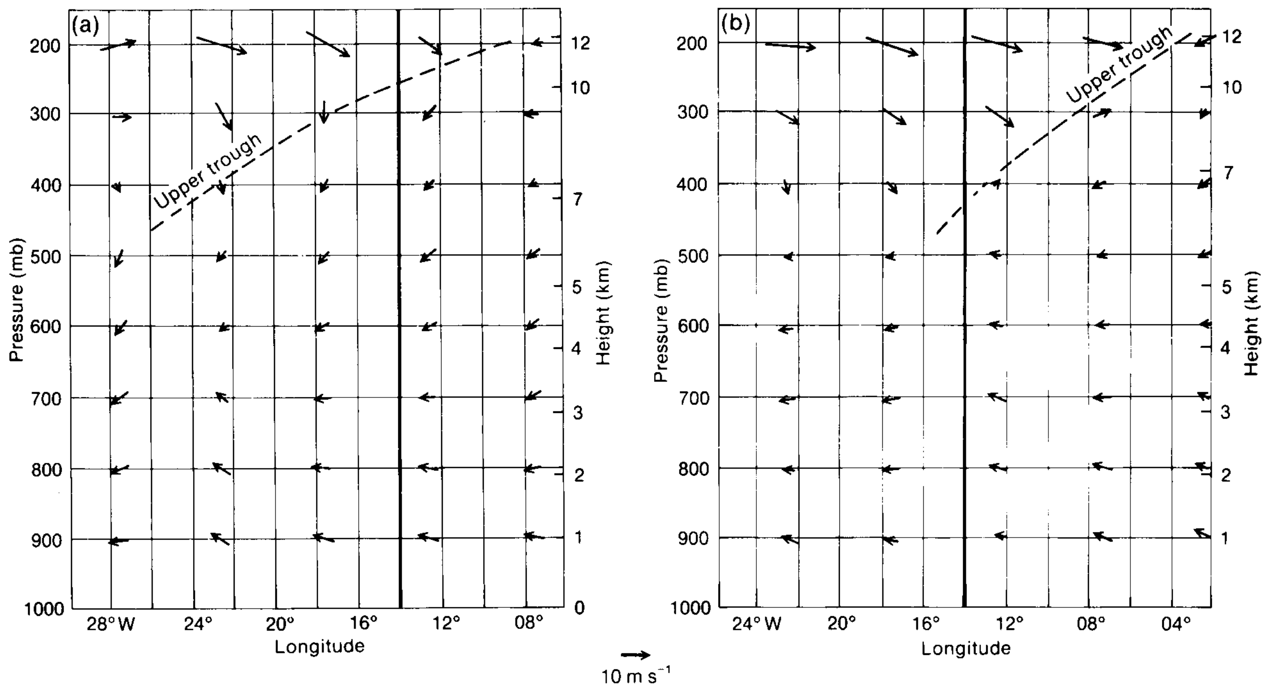

Figure 10. (a) Variation with longitude of the vertical profile of horizontal wind at the latitude of Ascension (8° S) for 12 GMT on 7 April 1986 from the Meteorological Office global model analysis, and (b) as (a) but for 12 GMT on 10 April 1986. The longitude of Ascension Island is highlighted.

middle- to upper-level winds will tend to inhibit shower activity but once the strongest winds have propagated downstream of the station and the height of the 25 kn isotach (for example) starts to increase, heavy showers are likely to develop as wind shear decreases.

(b) A slow lowering of the upper strong wind zone will lead to longer unsettled periods, roughly equal to the number of days that the 25 kn isotach takes to lower. This is simply because the larger the scale of the disturbance, the greater the period of passage over any one point.

It has been found that the disturbances which affect Ascension Island from time to time have the characteristics of the well-documented easterly waves of the North Atlantic. By study of satellite pictures, their origin is almost certainly central equatorial Africa, and rainfall and climate records confirm that March and April are the months of maximum activity. Also, retrospective inspection of the Meteorological Office archive of global operational analyses, using horizontal wind components, has provided encouraging evidence of the ability of the global model's analyses to depict upper-air disturbances affecting Ascension Island, which have the characteristics of easterly waves.

The scope of this paper has been limited by circumstances to model analyses. However, there is a good case for taking the next step in seeing if the global model can forecast the development and movement of easterly waves. If proved successful, then output in a form similar to the examples given should be made available to forecasters at remote locations such as Ascension Island in order to enhance forecasting techniques.

Acknowledgements

To R.M. Morris, Dr R.A. Bromley and Dr R.W. Riddaway for their constructive comments, to forecaster colleagues at Ascension Island for their co-operation during my 6-month detachment, especially the late J. Bush, and to S. Ineson for her help in accessing the analyses from the Meteorological Office global model.

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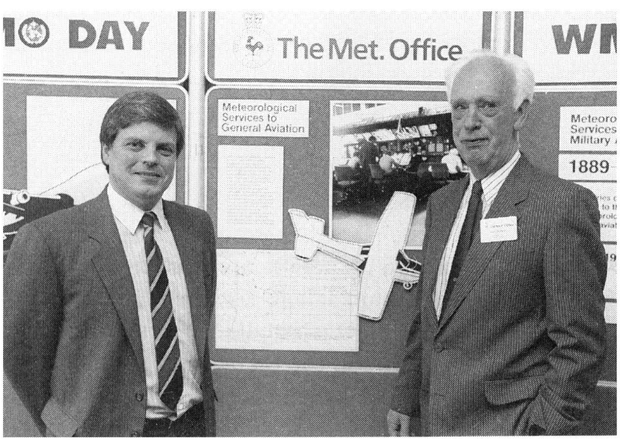
Notes and news

The Meteorological Office celebrates World Meteorological Day 1989

On 22 March this year the Meteorological Office at Bracknell entertained about 50 representatives of the civil aviation industry, as the UK contribution to the celebration of World Meteorological Day (strictly 23 March), and the theme for the year, 'Meteorology in the Service of Aviation'. The visitors represented a wide range of the aspects of aviation — carriers, operations, ground support, technical developments, controlling bodies — and several journalists from aviation publications also attended. Staff from Branches of the Office responsible for Marketing, and for Forecasting, acted as guides.

The guests first assembled in a room containing a series of display boards showing the development of meteorological services to both civil and military aviation. The boards commenced with the crude weather information made available to early balloonists, including a European surface chart for 22 March 1889, exactly 100 years previously, and ended with an example of a flight briefing chart for the same area for 22 March 1989.



Mr Ken Pollard (right), Director of Aviation Services, Meteorological Office, Bracknell and Mr Tim Guest, Manager of Flight Crew Briefing for British Airways, in front of one of the display boards.

The visitors were then welcomed by the Office's director of Marketing Services, Mr Francis Hayes, who introduced Mr Ken Pollard, the Office's Director of Aviation Services. In his address, Mr Pollard started by mentioning the Office's role in aviation meteorology as a World Area Forecast Centre (WAFC), Regional Area Forecast Centre (RAFC) and as a National Forecast Centre. As a WAFC the Office uses its sophisticated 15-level numerical forecast model, supported by powerful computer capability to produce global grid-point forecast fields of relevant meteorological variables. These are issued to RAFCs, with a back-up procedure involving the other WAFC at Washington to guard against rare cases of system failure. As an RAFC the Office uses the grid-point data to produce regional charts and significant weather charts, and these three types of data are interchanged with neighbouring RAFCs. Finally as a National Centre, RAFC-produced charts, low-level weather and wind charts, TAFs, trends, SIGMETs and aerodrome warnings are issued. The provision of equivalent tail-wind components also contributes to the support of general services to aviation.

The method of disseminating weather information to the aviation industry was next described; it was stressed that information transfer often used technologies which were becoming obsolete in contrast to the rapid developments in forecasting, and that this was a handicap for many aviation customers.

Mr Pollard went on to describe other meteorological products which would be of value to aviation operators but which at present were not available because of limitations in communications. These included weather radar and satellite images giving information about rainfall at airfields, forecasts of surface temperature, detailed wind forecasts for Air Traffic Controllers and objective forecasts of significant weather. Finally he spoke briefly about new methods of disseminating information for briefings, operations and flight planning.

The visitors were then shown around the Central Forecasting Office (CFO) where several demonstrations had been organized. These included:

Mr Martin Morris, Head of the Central Forecasting Office, Bracknell talking to visitors to the CFO.

MARS — the Met and AIS Retrieval System (AIS — Aerodrome Information System) being developed by the UK Civil Aviation Authority and due to become operational during 1989. This is an interactive system in which pilots can receive flight weather briefings, aerodrome information or other relevant data via visual display units linked to a central computer at London (Heathrow) Airport. It is planned that the terminals will be installed at all the larger airports in the United Kingdom and that this will become the standard briefing method.

Air Data — a commercial micro-computer-based system developed by Air Data Limited, a British company, for use by airline operators required to make operational decisions concerning the distribution of flight plans, evaluation of aircraft and route costs, and the management of aircrew. The occasion was used to promote their flight planning system which uses equivalent tail-wind components, calculated at Bracknell from all the forecast wind data available. This system reduces the errors introduced by interpolation from the standard coarse grid of data, inherent in all other flight planning systems.

The visitors were also shown a demonstration of the use of document facsimile for transmitting briefing charts (a system which is believed to have considerable potential with the steadily reducing costs of facsimile machines). Users could dial into the facility and automatically receive a pre-determined set of charts or other information. The use of the FRONTIERS weather radar system for producing 6-hour forecasts of rainfall over the United Kingdom and the general work of aviation forecasters were also explained.

The visitors were given copies of the literature from Geneva specially prepared for this important day in the WMO's calendar, including the interesting document WMO-No. 206 by J. Kastelein (President, WMO Commission for Aeronautical Meteorology) which describes the development of meteorological services for aviation.

The 3rd Workshop on Operational Meteorology, 2–4 May 1990, Montreal, Québec, Canada

The 3rd Workshop on Operational Meteorology, sponsored by the Atmospheric Environment Service of Environment Canada and the Canadian Meteorological and Oceanographic Society, will be held on 2–4 May 1990 at L'Université du Québec à Montréal. The principal theme of the workshop will be 'Weather Services of the Future'. A number of other topics in operational meteorology will also be included.

The Program Committee wishes to solicit papers on the following topics:

Short-term forecasting and meso-meteorology (observations, analysis, diagnostics, forecast techniques and dissemination)
Bridging the gap between research and operations
User requirements
Tomorrow's weather offices.

The format will consist of submitted papers, invited papers, panel discussions, and poster and demonstration sessions as well as 1- and 2-hour laboratory sessions. A brief introduction of each poster presentation will be given in an appropriate oral session.

Titles and reviewers' abstracts of 400–1000 words should be sent by 1 November 1989 to:

Stan Siok
Program Committee Co-chairman
Atmospheric Environment Service
3rd Floor
100 Alexis Nihon Blvd
Ville St-Laurent
Québec H4M 2N8
Canada.

Authors should indicate their preference for presenting their paper orally, in a poster session, as a demonstration, or in a short laboratory session (1 hour). Preferences will be considered to the extent possible. Abstracts will be evaluated on their relevance to the theme as well as on their quality. Papers not related to operational meteorology will not be accepted. Authors will be notified by 15 December 1989 with respect to both the acceptance of their abstract and instructions on the format of their papers.

Complete camera-ready papers of no more than eight pages, including diagrams, must be received by the program co-chairmen no later than 1 March 1990. A preprint volume will be prepared and distributed to workshop registrants. Papers and abstracts may be in either English or French. For additional information contact either Stan Siok (514-283-1139) or Peter Zwack (514-282-3304), Program Committee Co-chairmen.

Books received

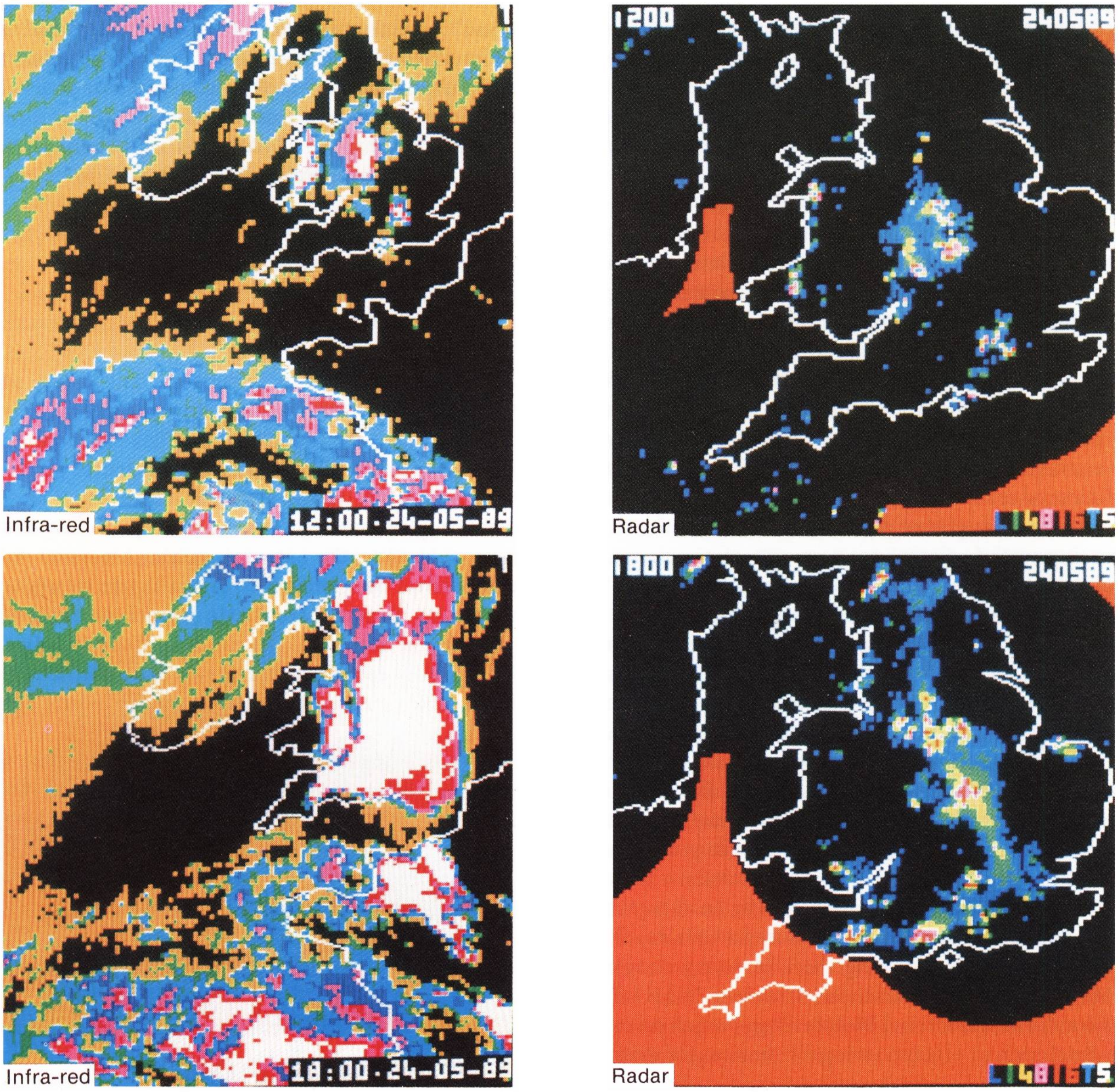
The listing of books under this heading does not preclude a review in the Meteorological Magazine at a later date.

Weather sensitivity and services in Scotland, edited by S.J. Harrison and K. Smith (Edinburgh, Scottish Academic Press, 1989. £25.00) is the outcome of a conference held at the University of Stirling in February 1988. It is an example of the benefits which can be derived from the effective use of weather and climate information, which could be a model to policy-makers world-wide.

Correction

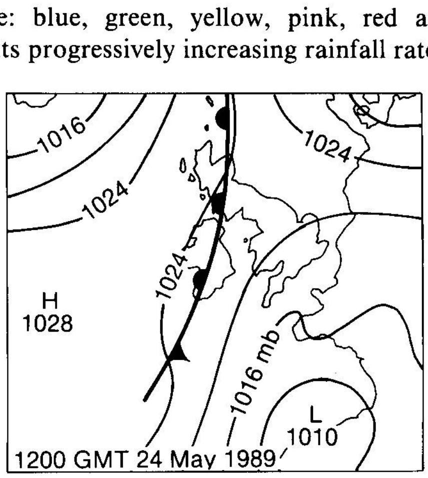
Meteorological Magazine, June 1989, p. 126, caption to Fig. 10. The section in brackets should have read: '(2123 GMT on 25 April 1986 to 0000 GMT on 27 April 1986)'.

Satellite and radar photographs — 24 May 1989 at 1200 and 1800 GMT



Thunderstorms affected many inland areas of England and Wales on 24 May 1989, and were locally severe with large hailstones, and causing flash flooding. South Farnborough in Hampshire recorded 56 mm of rainfall between 1200 and 1330 GMT.

The development and organization of the storms could be monitored by means of the frequent (½-hourly) images from Meteosat and the UK weather radar network. Shown above are images for 1200 GMT — in the early development phase of the thunderstorm complex to the west of London, and 1800 GMT — by which time the combined anvil cirrus shield of the mature complex covered much of central England. The surface chart for 1200 GMT is included for reference. In the infra-red images, the colour sequence: black, yellow, green, cyan, blue, magenta, red and white represents the transition from warm to cold. The radar colour sequence: blue, green, yellow, pink, red and cyan represents progressively increasing rainfall rates.



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Preparation and submission of articles

Articles, which must be in English, should be typed, double-spaced with wide margins, on one side only of A4-size paper. Tables, references and figure captions should be typed separately. Spelling should conform to the preferred spelling in the *Concise Oxford Dictionary* (latest edition). Articles prepared on floppy disk (Compucorp or IBM-compatible) can be labour-saving, but only a print-out should be submitted in the first instance.

References should be made using the Harvard system (author/date) and full details should be given at the end of the text. If a document is unpublished, details must be given of the library where it may be seen. Documents which are not available to enquirers must not be referred to, except by 'personal communication'.

Tables should be numbered consecutively using roman numerals and provided with headings.

Mathematical notation should be written with extreme care. Particular care should be taken to differentiate between Greek letters and Roman letters for which they could be mistaken. Double subscripts and superscripts should be avoided, as they are difficult to typeset and read. Notation should be kept as simple as possible. Guidance is given in BS 1991: Part 1: 1976, and *Quantities, Units and Symbols* published by the Royal Society. SI units, or units approved by the World Meteorological Organization, should be used.

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Diagrams must be drawn clearly, preferably in ink, and should not contain any unnecessary or irrelevant details. Explanatory text should not appear on the diagram itself but in the caption. Captions should be typed on a separate sheet of paper and should, as far as possible, explain the meanings of the diagrams without the reader having to refer to the text. The sequential numbering should correspond with the sequential referrals in the text.

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