

With Wind and Sword

the story of meteorology and D-Day

6 June 1944

by

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This paper should be read in conjunction with the photographs and weather maps included in *D-Day*, a booklet issued by the Meteorological Office in 1994.

PREFACE

This study was made at the request of the Chief Executive of the Meteorological Office, Professor Julian Hunt FRS. The author is grateful to him for support and for encouragement. The author also wishes to thank for their always willing help and inspiration the Librarian and Archivist of the Meteorological Office, Messrs M E Crewe and M Wood, as well as the staff of the Library of the Royal Air Force Staff College, Bracknell, of the Air Historical Branch of the Ministry of Defence and of the Imperial War Museum. Other colleagues have made their contributions in many ways and deserve thanks. Should there be any, all these share the glory; blame for the many defects is the author's alone.

Meteorological Office, Bracknell
March 1994

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1. INTRODUCTION

1.1 In early June 1944 the United Kingdom, in the west, and the Soviet Union, in the east, were the only countries in Europe which were not either neutral or occupied by Nazi forces. Planning and preparations for the Allied recovery of occupied Europe from the west, codenamed Operation OVERLORD, had been under way for many months.

1.2 First the Allied forces had to cross the English Channel and "to secure a lodgement on the continent from which further offensive operations can be developed" (*Battle Summary*, p.11). This assault on the beaches of Normandy was codenamed Operation NEPTUNE. It was a combined British and United States undertaking by all services of both nations. It was to be "the climactic day of World War II" (Michie, p.viii).

1.3 June was the month agreed with Stalin at the Tehran Conference for the start of the summer offensive of the Soviet forces (Churchill, p.6) and 1 May as the provisional date for NEPTUNE/OVERLORD (Pogue, p.167). The month of May had been selected for NEPTUNE since the weather then was often good (although sometimes northeasterly winds smothered the central and eastern Channel with 10/10 cover of low stratus cloud for days at a time). May would give a long summer for the campaign on the continent. Planning for May also allowed postponement until June. But gradually it became clear that the many complex preparations would not be ready and that the weather in June was usually more suitable than in May: on 1 February 1944 the Combined Chiefs of Staff, to whom General Eisenhower reported, agreed that OVERLORD would be mounted with a target date not later than 31 May. Later Eisenhower set 5 June as the "final" date for the assault, "subject, of course, to last-minute revision if the weather should prove unfavourable". (Report by the Supreme Commander, p.7)

1.4 As it turned out, May 1944 was generally a month of good weather, which would have favoured a cross Channel assault, and did favour "softening up" operations.

2. THE ROLES OF METEOROLOGY IN WORLD WAR II

2.1 Meteorological advice was central to the drama of the conferences at which the Supreme Commander decided when to launch the assault on Normandy. But, seen in the context of World War II as a whole, these were a few of a great many similar occasions. The difference lay in the scale of the operation and the weight of responsibility on those taking part. Battles are essentially outdoor activities: particularly because of the scales in space and time on which weather events occur, weather is almost always a factor and sometimes a formidable enemy. For all operations throughout the Second World War each arm of the forces had its own detailed requirements for combinations of elements such as air temperature, cloud, daylight, icing, moonlight, state of sea, tide, visibility and wind. Each received detailed weather advice for planning and for immediate operations. A general review of the Meteorological Office and its work during the Second World War is given by Stagg (1955).

2.2 Generals could use bad weather to conceal the movements of supplies and troops (Hinsley, Thomas et al, p. 223). Commanders needed to assess the likely effects of weather on the enemy's activities and so on. In choosing targets, air commanders needed to know if bombing would be through cloud using radar or could be visual. Commanders of fighter-bombers needed to know if it would be worth sending out aircraft over enemy occupied territory to carry out attacks against ground targets, such as flying bomb launching sites and trains carrying supplies. Navigators of bomber aircraft needed to know what winds and temperatures to expect on their routes and air pressures aloft over their targets. Photographic reconnaissance demanded clear weather [1]. At a tactical level, artillerymen needed to know the winds and temperatures which would affect the flight of their shells, those operating the fog dispersal systems (FIDO) for returning bombers

needed to know when they might be called upon and those operating smoke screens to defend factories from air attack needed to know how to deploy their resources [2]. Wind and weather affect most outdoor activities and so were significant in most wartime operations and often crucial.

2.3 Wind and weather were sometimes crucial.

2.3.1 The first full-scale trial of the assault technique for NEPTUNE was Exercise PIRATE, staged at Studland Bay, Dorset in October 1943. The proceedings were disrupted "by bad weather in the opening stage which necessitated a change of general plan and which shut down again after the assault and terminated the exercise prematurely." "Fog on inland airfields prevented the smoke-laying and bombing aircraft taking off and with the exception of the provision of air cover to the convoy at sea and dummy attacks by Typhoon aircraft against pre-arranged targets on the beaches, the air support plan as arranged was not carried out." (Stacey, p. 12).

2.3.2 During the final rehearsal for NEPTUNE, Exercise FABIUS, the weather was favourable at the beginning on 2 May 1944 but on 4 May a SW'ly wind freshened to Force 6 in the night and "the full programme had to be curtailed to avoid damage to landing craft" (*Battle Summary*, p.66).

"Whenever the weather permitted" recurs in many commanders' reports. [3]

2.4 Meteorologists served on the staff of most headquarters, down to individual airfield level in the Royal Air Force, for example. They served in all theatres of war, organizing observing and telecommunications systems, arranging weather intelligence and, as staff officers, using their scientific understanding to make the most accurate forecasts possible of weather elements so as to help the deployment and effective use of people and weapons

systems in operations. Flights of aircraft were maintained especially to provide the observations needed for weather forecasting. Some, known as THUM aircraft, made climbs over one place to obtain vertical profiles of pressure, Temperature and HUMidity: early on these were Gloster Gladiators, to which later were added Spitfires, in many theatres of the war.[4]

Other aircraft of RAF Coastal Command, based in the UK, Iceland and Gibraltar made long flights out across the Atlantic. [5] (Kraus; Ogden, 1985; Rackliff; Yates).

To support bombing operations over Germany, Mosquito aircraft flew sorties deep into enemy territory, often in broad daylight with no cloud cover, on Photographic and Meteorological Photography Aircraft (PAMPA) flights (Ogden, 1992).

As they were in most operations, forecasts and general advice were integral parts of the planning and briefing of the forces taking part in the deception operations around the time of D-Day known as Operation FORTITUDE (e.g. Ambrose, p.401; Chandler, p.1789; Leigh-Mallory, paragraphs 113-117; Ogden, 1994) and the essential gaining of air superiority, including the prevention of hostile air reconnaissance (Montgomery of Alamein (1946), p.4432).

2.5 In 1944 three meteorological services were operating in the United Kingdom: the Meteorological Office, the Royal Navy's Naval Weather Service and the Weather Service of the United States Army Air Forces (USAAF).

2.5.1 The Met. Office had had an identifiable existence since 1854 and, together with the Royal Air Force and Civil Aviation, had been a founder part of the Air Ministry since that unifying department was set up by the UK government after the First World War. Under Dr N K (later Sir Nelson) Johnson (1892-1954), the Office expanded greatly during the Second World War, exerting

technical control on nearly ten thousand men and women by D-Day. Inevitably, only a few were pre-war professional meteorologists. Many forecasters had been schoolteachers in civilian life, chiefly of mathematics and physics. Most served for the duration of the emergency only. This involved a considerable effort in training: a history of this effort is given by Ogden (1986, p.200) and references contained in that paper.

Throughout the war the Met. Office as a whole was a civilian establishment of the Air Ministry, although most meteorologists were in uniform by April 1943 [6]. Until 1942 Met. Office staff serving abroad in theatres of war were reservists in the Meteorological Branch of the Royal Air Force Volunteer Reserve. In UK forecasters and headquarters officers remained civilians. Increasingly assistants and other junior staff were recruited as airmen in the RAF and airwomen in the Women's Auxiliary Air Force (WAAF). (A personal account of life as an airwoman meteorologist in Bomber Command is given by Spear (1988). By June 1943 over 1800 WAAFs had been enrolled in the Office and had taken over almost the entire complement of outstation assistant posts in the United Kingdom (Ogden (1986, p.200))).

From 1 November 1942 forecasters in operational theatres overseas were commissioned in the RAF Volunteer Reserve. From 1 April 1943 those in operational Home Commands of the RAF also went into uniform. In non-operational Commands at home forecasters remained civilians. On posting from one Command to another a forecaster's status could change so that some staff made more than one change from uniform to civilian clothes and vice versa. (AP 1134, p.561.)

2.5.2 The Royal Navy separated out its own Weather Service from the Naval Division of the Met. Office when

the Admiralty created the Fleet Air Arm in the years before World War II. The Naval Weather Service shared much of the same telecommunications infrastructure and rested on the same science base as the Met. Office. Ashore and afloat, forecasters in the Navy held commissions in the Instructor Branch, as they still do. The Navy's forecasting centre in 1944 was in the "Citadel" at the Admiralty in London. A personal account of the Naval Weather Service during World War II is given by Watts (1988).

2.5.3 The Weather Service of the USAAF had its own military, professional and telecommunications structures. Its United Kingdom headquarters at Bushey Park, Teddington, on the Thames to the west of London, was known as WIDEWING.

2.6 As in most States at war, newspaper forecasts and broadcast information about current weather, including the free and open exchange with other national meteorological services, were suppressed in the United Kingdom at the outbreak of World War II, so as to deny helpful intelligence to the enemy. However, because of the way weather pervades many activities, meteorological advice was needed more than ever at all levels of government and command. To provide this the three meteorological services exchanged weather information, co-operated at the planning, scientific and infrastructure levels and enjoyed some informal social contact, chiefly at the higher levels.

2.7 The wise commander learned the limitations of the forecasts as he did of many of the other tools available to him. Nevertheless he learned how to make them work for him. The most senior commanders knew that weather observations came not only from Allied sources: intelligence sources often provided them for German occupied and neutral territory (Winterbotham, pp.91 & 92) and from U-boats. (By the beginning of May 1944 the making and transmission of weather reports was the main function of

U-boats in the Atlantic and this became even more important for the Germans in the later stages of Overlord (Hinsley, Thomas et al. p.125 footnote, also pp.430 and 489)). The number of reports varied between 2 and 12 depending on the number of submarines at sea; their quality was not always satisfactory because of wireless and coding defects (Air Ministry/USAFE p.39). According to Hinsley and Stripp (1993, p.v), the Allied intelligence community was reading some 4000 German high grade signals a day as early as the end of 1942. Dakin (1993, p.53), Taunt (1993, p.105) and Noskwith (1993, p.121) suggest that routine headings such as "Weather Forecast" helped in deciphering this mass of German signals and Lucas (1993, p.248) writes that almost standard messages from German weather reconnaissance aircraft over the North Sea helped in the same way. Ogden (1993) discusses network Beagle, a clandestine meteorological observing network which sent reports to wartime Britain from Belgium, and Bartkowski (1992) reports on a similar network in Poland [7,8].

2.8. Information from such sources was distributed to larger forecast offices by teleprinter on a strict "need to know" basis. Classified messages intended only for main stations with a need to know were preceded on the teleprinter broadcasts by bells and the code words MANX MANX MANX, to be interpreted as "No tails", and DIP, DIP, DIP, to be interpreted in the same sense as dipping the light: smaller stations were cut off from the broadcast whilst these messages were being sent.

2.9 The meteorological organization as it worked in connection with D-Day is shown in Figure 1.

3. PLANNING FOR D-DAY

3.1 Operation NEPTUNE was

"the most complicated and most difficult that has ever taken place. It involves tides, winds, waves, visibility, both from the air and the sea stand-point, and the combined employment of land, air and sea forces

R O T A T I N G L E A D E R S H I P

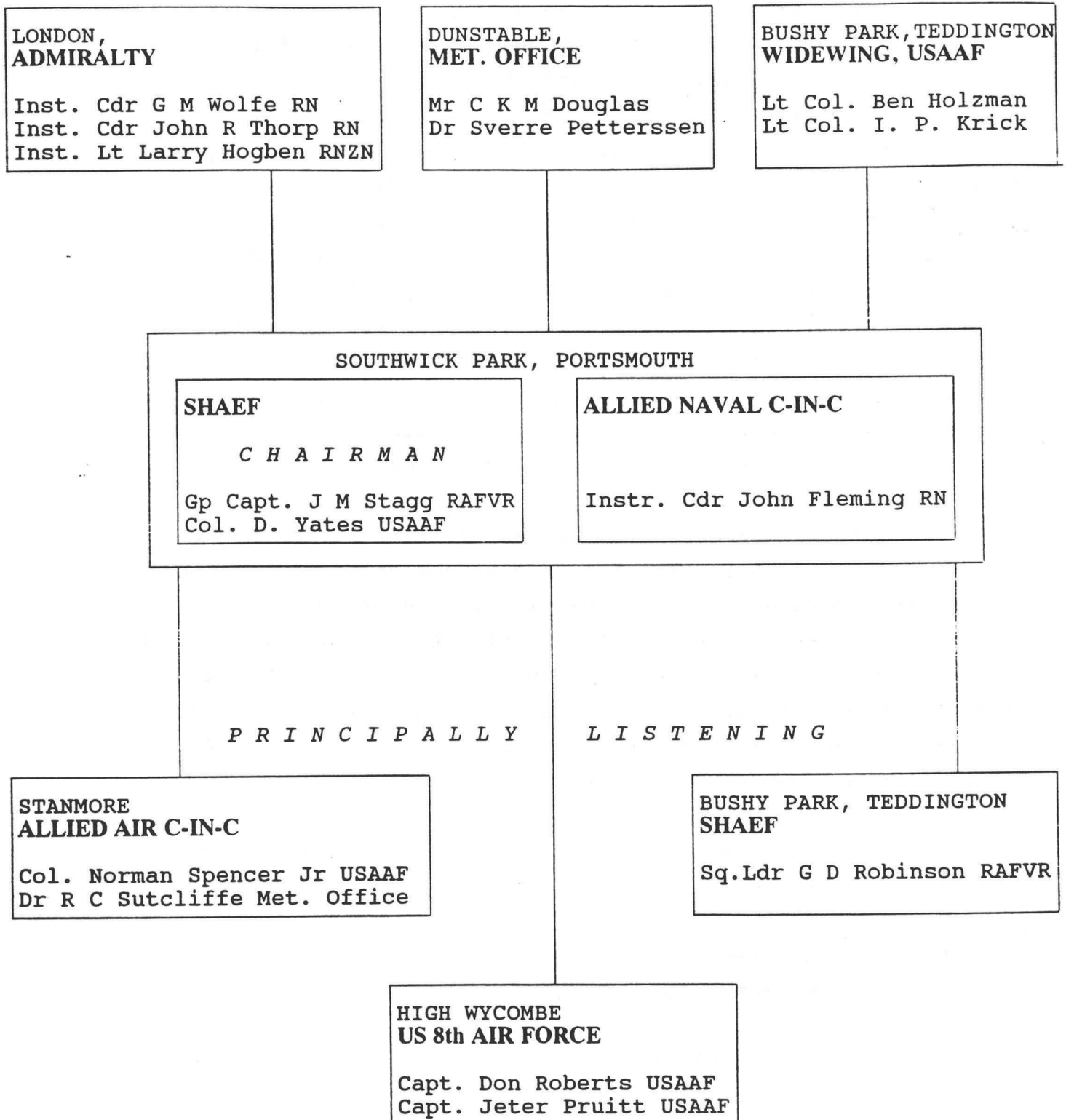


Fig.1 Meteorological organization for telephone conferences during the first few days of June 1944

in the highest degree of intimacy and in contact with conditions which could not and cannot be fully foreseen."

(Mr Winston Churchill to the House of Commons on 6 June 1944 (James))

For the naval part of the operation alone, the Operation Orders ran into nearly a thousand pages of foolscap and, when bound, a set made up into a volume about three inches thick, apart from numerous Appendices (Chalmers, p.208). Eisenhower had more than 2 500 000 men and women under his command (Ambrose, p.403). It was their "privilege to take part in the greatest amphibious operation in history." (Ramsay's Special Order of the Day, quoted by Chalmers, p.222.)

Weather requirements for D-Day

3.2 Minimum conditions representing the weather requirements of the three arms of the Expeditionary Force were never wholly agreed. Criteria which the Meteorological Section at SHAEF kept in mind are listed on p.2 of a report made on 22 June 1944 on the Meteorological Section SHAEF on the *Meteorological Implications* in the selection of the day for the Allied invasion of France. The report is copied as Annex B. As late as 1100DBST on 3 June at the Fifth Allied Air Commanders' Conference, there was still unresolved discussion between Air Chief Marshal Harris and the Air C-in-C, Air Chief Marshal Leigh-Mallory, on minimum weather requirements (Freeman, Minute 12, Appendix VI/122).

3.3 For central planning and advice before the event, the staff of the Chief of Staff to the Supreme Allied Commander (COSSAC) in Norfolk House, St James's Square, London, had simplified the various arms' weather requirements for NEPTUNE to

(a) D-Day to be within the period of one day before to four days after new or full moon;

(b) D-Day itself to be quiet and followed by a sequence of three quiet days; (A quiet day was defined

as one with wind less than Beaufort Force 3 onshore and Force 4 off-shore on the Normandy coast of France.)

(c) Cloud to be less than 3/10 cover below 8 000 feet and visibility more than 3 statute miles;[9]

(d) Alternative to (c), cloud base generally above 3 000 feet and with morning mist or fog not excluded.[9]

Climatology

3.4 Statistics from past years' weather were known to be quite an unreliable and unhelpful guide for the actual selection of D-Day (*Meteorological Implications*, p.4). Nevertheless they were a helpful planning guide. Weather records maintained in the Met. Office were examined and the frequencies with which each of these events had occurred in the past were calculated. Of course, the more elements which had to be right at the same time the smaller the probability of occurrence. The probabilities of obtaining several combinations were estimated and expressed as racing odds: (*Meteorological Implications*, p.3; AP 1134, Appendix No.9)

	<u>Chances to 1 against</u>		
	May	June	July
I			
b and d without a	4	2	5
b and c without a	9	4 1/2	19
II With new or full moon			
b and d with a	11	6	16
b and c with a	24	13	50
III Full moon only			
b and d with a	24	13	33
b and c with a	49	24	100

3.5 The need to have a new or full moon (Category II above, ensuring a time of low tide close to that of sunrise on the Normandy beaches so that mines and obstacles could be countered) roughly trebled the odds against having particular wind and weather (Category I). To have a full moon (Category III), so that its light could assist Allied Airborne Forces landing before the sunrise landings on the beaches doubled the odds again.

3.6 During the planning, astronomical and tide tables showed that tide and moonlight combined favourably on 5, 6 and 7 June. The tide, but not the moonlight, was right again two weeks later. But at either of these two periods, because of the combination of conditions needed, the odds from the outset were about 10 to 1 against the weather being even broadly acceptable (i.e. b. and c. or d. with a. above.)

Seven day forecasts

3.7 During the planning, too, it became clear (Stagg (1971), p.18), that the Supreme Commander would want seven day forecasts. These were to allow him to choose four days ahead a D-Day when wind and weather on D-Day would not prohibit landings, because of continued gales or persistent low cloud, and two or three days following D-Day when wind and weather would allow a continued building up of the forces in Normandy and continued air cover for them.

3.8 At Widewing, Colonel Irving P Krick USAAF had great faith in statistical and analogue methods for five day forecasts which had been amongst the methods tried, and not found useful, by Met. Office scientists working under the direction of the Meteorological Research Committee. The few British meteorologists directly involved in forecasting specifically for NEPTUNE were aware of these results. In a SECRET report to the Secretary of State for Air, on 31 March 1943, (MRP 82) the Meteorological Research Committee [10] reported

"Investigators in various countries have from time to

time claimed that they had devised successful methods of producing weather forecasts for epochs of a week to a month ahead. Whilst the Committee were not satisfied as to the theoretical soundness of any of these claims, the practical value of even an empirical method of long-range forecasting is so great that it was decided to test by practical trial the Weickmann method of pressure wave analysis, which appeared to offer the greatest chance of success. A six months' full scale trial has accordingly been made, involving the employment of some thirty personnel. A full and critical examination of the results has not yet been completed, but the indications so far are that the method does not possess the degree of reliability hoped for."

3.9 Through a sub-committee, under the Chairmanship of Professor G I Taylor [11] the Committee oversaw further work on various methods of extending the time span for which forecasting was possible (for example another trial of 6 day forecasts at Stonehouse, Glos., between mid-September and mid-November 1943 (MRP 175)) but it was beyond what could be achieved with the knowledge and tools available at that time [12,12a].

3.10 British forecasters also knew from their own experience that trying to see 48 hours ahead in western Europe in such changeable weather was at or beyond the limit of what was then scientifically possible. The fact that the need for useful forecasts for five or seven days ahead was paramount could not alter this sober reality and could not somehow make responsible forecasts possible. The Second Army's NEPTUNE BIGOT TOP SECRET Operation Order No. 1, dated 21 April 1944, (Headquarters Second Army) gives the Army's understanding of the position:

"Although the trend of the weather can be forecast for some three days ahead, it cannot be expected that a sufficiently accurate weather forecast to determine if the operation can take place, can be made further ahead

than 24 hours. The assault forces sailing earliest have to leave harbour some 36-40 hours before H hour, and their sailing must therefore be ordered on a trend forecast. The Supreme Commander will make his final decision on the weather forecast issued at H minus 24 hours."

In practice, in 1944, even given a good coverage of state of the art observations, wind, state of sea, visibility and cloud, could be forecast, with some uncertainty, only for up to 24 hours ahead and with less certainty out to 48 hours. When it was possible to forecast the beginning of a good spell it was not possible to forecast the duration of the spell. (Freeman, para.98.) [13].

3.11 Indeed, 50 years later in 1994, despite much research and much progress, forecasting for the period 5 to 10 days ahead is still a topic of active research, in, for example, the European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, Berks, UK, and a lack of observations is one of the constraints on forecast accuracy.

3.12 Planners were also aware (Harrison, p.130) that in the autumn of 1940, following Goering's failure to knock out the Royal Air Force in the Battle of Britain, a succession of postponements of the German invasion, Operation SEELOEWE, had achieved nothing. The Germans thought they needed a relatively long period of almost flat calm (like that which blessed the British evacuation from Dunkirk under the direction of the then Flag Officer, Dover, Vice-Admiral Bertram Home Ramsay (Retired) in May 1940. (Schofield, p.114.)). Such periods were rare and could not be forecast. Instead, the weather became more stormy and unpredictable as the autumn of 1940 advanced until, finally, Operation SEELOEWE was called off. [14]

4. EARLY NEXT WEEK? - OR WAIT?

4.1 The target date for Operation NEPTUNE "in respect of which

all preparations will be completed is 31 May 44; the exact date of D-Day will be notified in due course." (Headquarters Second Army, Appendix A, paragraph 21).

4.2 On 6 May 1944, in a letter to General Marshall in the US, General Eisenhower included "accuracy of weather predictions" in a list of five "worst problems" (Chandler, p.1849). By the last week in May the Supreme Commander had dealt with all the problems which were in his power to settle: weather was the remaining most important unknown. Once a week throughout May, then each day, and eventually twice a day, his Chief Meteorological Officer, Dr J M Stagg [15] of the Meteorological Office, his Deputy Col. Donald N Yates USAAF, and Instructor Commander John Fleming RN [16] used the resources of, and tried to co-ordinate the conclusions of, the three meteorological services of the Air Ministry, Admiralty and USAAF, to foresee each critical weather element; they presented to Eisenhower, his Commanders in Chief and their Chiefs of Staff their assessment of the meteorological situation based on (a) telephone conferences with the meteorological forecasting centres at Widewing, Dunstable [17] and the Admiralty, (b) telephone discussions with Squadron Leader G D Robinson still at the small SHAEF meteorological office next to the war room at the more permanent SHAEF headquarters at Teddington and (c) the charts plotted in Commander Fleming's small meteorological office just outside Eisenhower's Forward Headquarters at Southwick House, near Portsmouth [18]. In their turn, each often already briefed by his own meteorological adviser, the commanders learned how to assess these "agreed forecasts". Years later, Eisenhower noted: "...for some days I had required a forecast covering the ensuing 48 to 72 hours, so as to compare forecasts with reality" (Chandler, p.1902).

5. THURSDAY

5.1 On Thursday 1 June as the Supreme Commander drove into his office with his naval aide, Captain Harry C Butcher USNR, there was a slight drizzle: they cast apprehensive glances at the sky. Later the sun came out and in mid-afternoon there was low cloud.

With D-Day expected on 5 June and the decision to go almost imminent, everyone was very weather-conscious. Eisenhower said that the previous evening there was nothing in the weather forecast to be unduly disturbing (Butcher, p.479). But late May's quiet weather had given way to unseasonably unsettled westerly winds, with moving low pressure areas and weather fronts. General Walter Bedell Smith (1956), Eisenhower's Chief of Staff, wrote "as May wore out, June dawned dark and stormy with a gale over the Channel. Up at SHIPMATE - code name of the Advanced Command Post on the bluff - we shivered in our tents and trailers. The meteorologists in their Nissen huts near Admiral Ramsay's headquarters worked desperately, searching ... for clearer skies. They were not trying to predict the weather they were trying to make it. Commanders' meetings at Southwick House were charged with worry. The sober fact was that the worst June storm in twenty years was whipping the Channel".

5.2 In May, when the weather had been more settled, the three forecasting centres often agreed, but when the weather became more unsettled in early June it was rare for them to agree on the most likely developments or on the period for which forecasts could be made responsibly.[19]

6. SATURDAY - POSTPONE!

6.1 In the evening of Saturday 3 June the weather outside the Headquarters was reasonably fair and at 2130 hours Double British Summer Time [20] it was still light. Inside, General Eisenhower and his commanders were seated informally in easy chairs. Group Captain Stagg told them that his associates and the three forecasting centres were agreed that high pressure over France and low pressure further north would maintain winds in the Channel from west to southwest, up to Force 5 in places, and rough seas. Warm moist air would bring heavy cloud, mainly 10/10 base about 500 feet, though on occasion the base might be down to sea level. (Freeman, p.211, based on notes kept by AVM Robb who was present.) In effect, the forecast was for weather on the other side of the English Channel which was too bad for landings

on the first choice for D-Day, Monday 5 June, and for too much cloud for successful air operations.

6.2 The Supreme Commander thought "that the desirability for getting started on the next favorable tide is so great and the the uncertainty of the weather is such that we could never anticipate really perfect weather coincident with proper tidal conditions, that we must go unless there is a real and very serious deterioration in the weather" (Eisenhower in Ferrell, p.120 and Chandler, p.1905). Moreover he "realized that it was unlikely that so great an operation could be started and then stopped again without complete loss of secrecy. Loading of ships had begun by 1 June, and it was clear that putting back to harbour and unloading ships would give rise to mishaps. Worse still, a delay meant an additional chance for the enemy's pilotless aircraft (Vls) to begin their operations [21], or the possibility that the next favourable tides in mid-June would have even less satisfactory weather." (Pogue, p.168). Nevertheless that Saturday evening, in fine weather at Southwick House but on a forecast of bad weather on the Normandy beaches, Eisenhower made "a provisional decision to hold up operation NEPTUNE on a day-to-day basis". This provisional decision was confirmed at an early meeting the next morning; convoys already at sea were ordered to turn back and seek shelter.

6.3 Twice before Eisenhower the soldier had had to make the final decisions on essentially naval matters: the landings in North Africa in November 1942 (Operation Torch) [22] and the invasion of Sicily in June 1943 (Operation Husky). Both were successes, both involved winds which were barely tolerable and both achieved an element of surprise (Chalmers, p.219). Before taking the decision to launch Husky, for example, Eisenhower spent some hours with the Naval Commander-in-Chief Admiral Andrew B Cunningham whose meteorologists brought in frequent reports and forecasts. After the decision to launch the assault was taken winds "increased alarmingly. There was nothing we could do but pray, desperately." (Eisenhower, p.190).

7. SUNDAY - GO!

7.1 On Sunday 4 June 1944 Allied troops entered Rome, the first European capital to fall to the Allies; but this was not in the minds of those at Southwick House. That evening Eisenhower, the Commanders in Chief and their Chiefs of Staff again assembled in the library at 2130DBST, for what Croswell (1991, p.243) has called one of the most important councils of war in military history. Each C-in-C was, as usual, already briefed by his own meteorological adviser. Admiral Ramsay, for example, had studied the situation closely with Commander Fleming and had made his mind up that the assault must be made on Tuesday morning (Chalmers, p.219). Outside there was driving rain, "the trees in the copse opposite were swaying in the rising wind and the clouds scudding across" (Schofield, p.81) as a cold front passed. Stagg was accompanied by Yates and Fleming. They knew that a naval ship, code-named WANTAC, specially stationed in an area south of Iceland to make weather observations to support the forecasts for D-Day, had been reporting rising pressure since 1000 GMT (1200 DBST) that morning. Earlier they had lost confidence in messages from this ship (Stagg, (1971) p.108) but now if these rises continued a ridge of high pressure could be developing behind the front.[23]

7.2 In a tense atmosphere Stagg stated that there had been a very marked change since the previous meeting. He explained that the front giving the rain outside had been unexpected earlier but was now moving southeastwards and would clear the assault area within two or three hours [24]. Behind the front there could be an interlude in the unsettled weather over the Channel and assault area just for the critical hours on Tuesday 6 June. Winds were up to Force 6 in places as he briefed but would moderate during Monday 5th; (rough seas and heavy swell take longer). On Monday night and at H-Hour on Tuesday morning weather would be suitable for the heavy bombers. Operations later on Tuesday might be curtailed by large areas of cloud, but the cloud was likely to be high enough to enable the fall of shot to be spotted for the

Naval heavy guns.

7.3 The Deputy Supreme Commander, Air Chief Marshal Tedder had been a professional engineer. Before the war, he had been Director of Research and Development Royal Air Force in the Air Ministry. He knew what meteorological research was going on and of the differing assessments by the three forecasting centres (Stagg (1971), p.95). As a pilot and senior air force commander he had also had much experience in comparing meteorologists' forecasts with the eventual weather. He asked Stagg how much confidence he had in the forecast and was re-assured that Stagg was confident that a fair interval would follow the front. Beyond that Stagg had not much confidence in the generally stormy weather patterns over the Atlantic quietening down after Tuesday, but there was a reasonable chance that the Azores anticyclone might extend northwards again (Stagg (1971), p.113). Eisenhower asked how many hours he could count on for the attack. Stagg replied that the morning would be fair and good weather might last through the afternoon. Each C-in-C, concerned with his own arm, put further questions. Eisenhower agreed with Leigh-Mallory that the Air would be handicapped. In response to an enquiry from Eisenhower, Montgomery said "I would say Go!". The order was given [25]. According to Michie (p.146) "The message which set the vast machinery of invasion was prosaic:

"Reference movement instructions issued for movement 5 June subsequently postponed by our message QM PW of 041415. Road and rail parties will now move 6 June same time and routes. All informed."."

7.4 Paradoxically, for a second time, the decision had been made on the basis of a forecast of weather for the assault which was the opposite of what those hearing the forecast could see for themselves outside the window.

7.5 After this Sunday evening decision, leaving Southwick House beneath a still overcast sky, Rear Admiral (later Admiral of the

Fleet) Sir Philip Vian, Commander of the Eastern Task Force, commented "It looks to me like bloody nonsense". (Schofield, p.82) [26]. Nevertheless, the forecast was maintained and the order confirmed after a further briefing at 0415 DBST on Monday 5 June 1944 [27]. For the third time Eisenhower, having taken meteorological advice, was knowingly launching an invasion in weather which many thought unsuitable and which he knew was less than ideal. [28,29]

8. MONDAY

8.1 In his diary for Monday 5 June Admiral Ramsay wrote: " Had a final meeting at 0415. This time the prophets came in smiling, conditions having shown a considerable improvement. It was decided to let things proceed. The wind was still fresh, and it is clear that forces will have an uncomfortable initial journey " (Chalmers, p.221.)

8.2 Less than five hours later, at 0900DBST on 5th June, the first groups of landing craft sailed from Portsmouth and from then on there was a constant stream of ships passing the Needles and Nab Tower. As the first convoy left Spithead the wind was west, force 5, decreasing in force at times but with strong gusts; waves were five to six feet in mid-Channel. These conditions were severe but just tolerable [30]. They tested the crews of the landing craft and were unexpected by the Army, which, like the Germans in 1940, had maintained during planning that fine weather and a calm sea were essential for the assault. (Battle Summary p.81; Admiral Ramsay's Despatch, para. 31.)

8.3 Whilst the troops did not even consider the possibility of failure of the operation as a whole (Imperial War Museum D-Day audio tape) and the detail of the planning did not allow for failure, General Eisenhower knew the conditions were marginal. In private on 5 June he prepared a rough draft of a communique he intended to issue if NEPTUNE failed. "He stuck it in his pocket and forgot about it until several weeks later, when he found it. I asked him for it as I thought it of interest, since it showed

how he instinctively assumed responsibility, particularly if anything went wrong." (Butcher, between pp. xvi and xvii):

"Our landings in the Cherbourg-Havre area have failed to gain a satisfactory foothold and I have withdrawn the troops. My decision to attack at this time and place was based upon the best information available. The troops, the air and the Navy did all that Bravery and devotion to duty could do. If any blame or fault attaches to the attempt it is mine alone."

9. TUESDAY - THE ASSAULT!

9.1 On Tuesday 6 June wind and weather permitted airborne operations and during the hour before the landings a mixture of cloud and clear air allowed visual bombing of the shore defences in some places and not in others. (*Report by the Supreme Commander*, p.27.) The sea was still rough and many men were sick during their 17 hour crossing and felt unwell during the critical early minutes on the beaches. High seas added to the difficulties in getting ashore. "Landing craft were hurled on to the beaches by the waves, and many of the smaller ones were swamped before they could touch down. Others were flung upon and holed by the mined underwater obstacles. Numbers of the troops were swept off their feet while wading through the breakers and were drowned, and those who reached dry land were often near exhaustion." Waves caused some of the landing craft to lag and there were some losses, (*Report by the Supreme Commander*, p.28) especially of tanks fitted with special flotation skirts. "The cloud conditions were not very favourable for bombing when over 1,300 heavy bombers of the Eighth United States Air Force and eight medium divisions of the Ninth United States Air Force, swept over the target area." (*Montgomery of Alamein*, 1946, p.4437, col.2). During the morning a hazy fog covered Normandy; it cleared around mid-day (Zimmerman, p.188) [31,32]. In southern England General Montgomery spent the day in the garden (*Montgomery of Alamein*, 1958, p.249). In the evening he sailed for France and reports that off the beaches of Normandy on 7th

"The wind and sea had now dropped, the sun was shining".

10. THE GERMAN VIEW

10.1 The Germans too had been preoccupied with tides, wind and weather. Meteorologists there had resources they would never have had in peacetime. A special group made forecasts so as to know when to expect the invasion. The defenders expected the invasion to begin "of course, with little wind and sea." (Ruge, p.323). Professor Ludwig Weickmann was brought in to co-ordinate forecasts prepared by army, navy and air force meteorologists. If conditions looked likely to favour an assault in the early hours at any particular point along the Atlantic Wall, troops there would be alerted. During 4-5 June, despite the favourable early morning low tides, German meteorologists expected winds of Beaufort 5 or 6 and, on the light wind criteria given them, considered a landing on the Normandy coast by the Allies would be too risky; indeed, on 5th, German naval craft, attempting to put to sea for mine-laying operations, were forced back into harbour when the stormy conditions threatened to overturn them. German commanders in the west stood down. (Flohn in *Fort Ord*, p.94; Krancke, quoted by Morison, p.107; Ruge, p.330; Schwerdtfeger (1986, pp.159-161); Shirer, Chapter 29; Zimmermann, p.185).
[33]

11. CONCLUSION

11.1 The first observation from the beach-head plotted at ETA, the Dunstable wartime central forecasting headquarters of the Met. Office, was from Sword Beach, north of Caen, for 1500 DBST, some 8 hours after the first landings: mainly sunny, wind NW'ly Beaufort force 4, small amounts of broken cumulus cloud above 4000 feet, good visibility and a temperature of 59 degrees Fahrenheit (15C).

11.2 Eisenhower and his Commanders in Chief received sound meteorological advice at the conferences on 3, 4 and 5 June 1944. The Supreme Commander and his Cs-in-C were experienced decision makers but still took pains to learn how to benefit from such

advice. This allowed the Allies in the west to assess risks and make use of weather that was barely tolerable, and below some of the agreed minima, to give them the element of surprise.

11.3 Three days later, in the east, Stalin synergetically launched the first large Soviet offensive of 1944: Operation Neptune had been the first step in the long march of Hitler's last summer.

POSTSCRIPT

The Combined Chiefs of Staff had agreed in February 1944 that Overlord would be mounted with a target date not later than 31 May 1944. Eisenhower had indicated that the exact date of the assault should be left open and subject to weather conditions prevailing during the first week of June. (*Report by the Supreme Commander*) This gave him a little leeway. Although in early June "Human endurance and security considerations dictated no further delay" (Jones) [34], one of the Supreme Commander's options on 4 and 5 June was to wait for better weather at the time of the mid-June tides. Any postponement beyond 7 June "would have necessitated waiting until 19 June for a similar favourable tidal period. This later date would have necessitated the acceptance of moonless conditions." (*Report by the Supreme Commander*, p.7). Had General Eisenhower not decided to launch the assault in early June he would have been making decisions day by day in the run up to 19 June. Charts for this period, when German V1 pilotless aircraft were being directed at London, are shown at Fig. 2.

On 15 June 1944 a depression moved eastwards to the north of Scotland and then sank southeastwards across the North Sea to reach Germany by noon on 17th. By then a ridge of high pressure had built from Ireland to Norway. This gave northerly winds over the North Sea and English Channel. On 18 June an anticyclone lay over the British Isles and the weather was fine. But winds over the North Sea and English Channel were veering slowly from N'ly to ENE'ly. They brought enough low cloud to cause Eisenhower to write to General Marshall on 19 June "the whole eastern coast of the Channel is tied up in the worst weather we have yet had" (Chandler, p.1936). Then, as winds freshened and spring tides approached, the waves arriving at the Normandy beaches came for some time from the direction with the longest fetch: sea extended uninterrupted from the beaches through the Straits of Dover and into the North Sea. Thus, whilst winds were measured as strong, on the whole Beaufort Force 6, but not gale force, (e.g. Stagg (1971), p.126, Morison, p.176,177), waves with heights averaging eight feet (*Battle Summary*, p.139), which

seemed huge to those involved (Chalmers, p.238), were breaking on the beaches; the western Mulberry Harbour, still incomplete but designed to last for 90 days, was destroyed [35]. Commanders later described these winds, formally as "a north-easterly gale, unexpected and unforecast" which "at once stopped all unloading to the beaches," (Admiral Ramsay's Despatch, p.5120) and informally as "a gale of hurricane strength" (Tedder, p.553), "the hurricane" (Eisenhower in Ferrell (1981), p.121) and "a gale of unprecedented violence. Just when we needed fresh divisions to proceed with our plans and retain the initiative, those divisions were in ships anchored off the beaches and unable to land." (Montgomery, 1958, p.257). Eisenhower wrote that "the consequences of the gale were so serious as to threaten our very foothold on the Continent." (Chalmers, p.239).

A decision on 4 June to postpone the assault would have led to one being taken on 17 June to begin the assault on 19th [36,37]. It is almost certain that forecasters would not have foreseen strong NE'ly winds, nor very rough seas breaking on the beaches: they would have set in train a majestic tragedy.

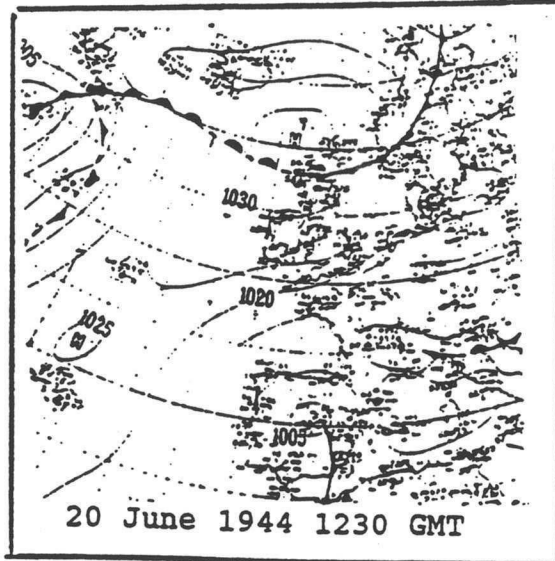
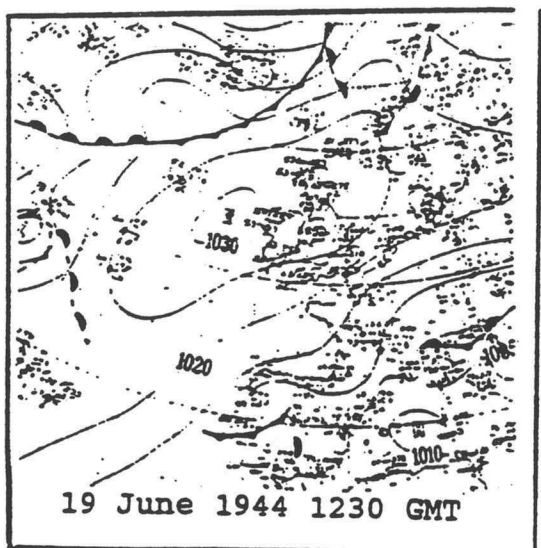
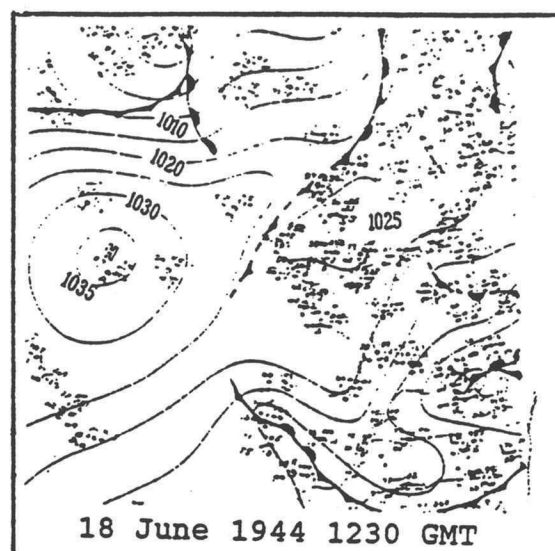
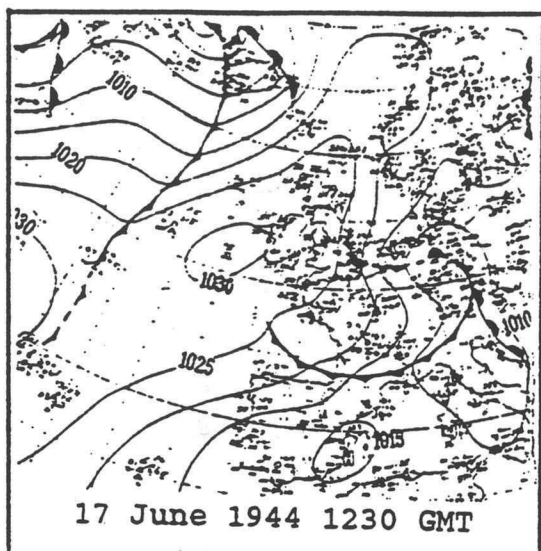
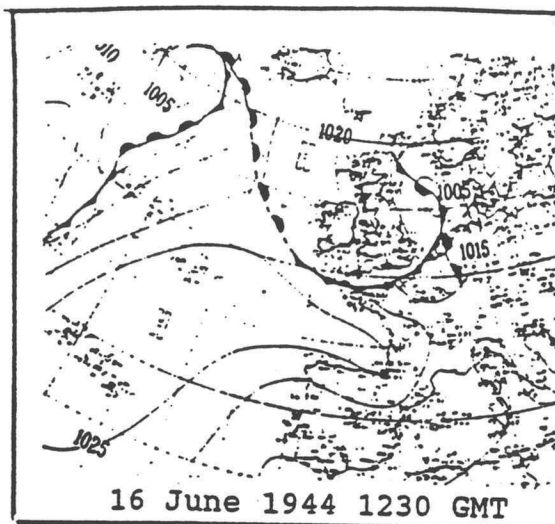
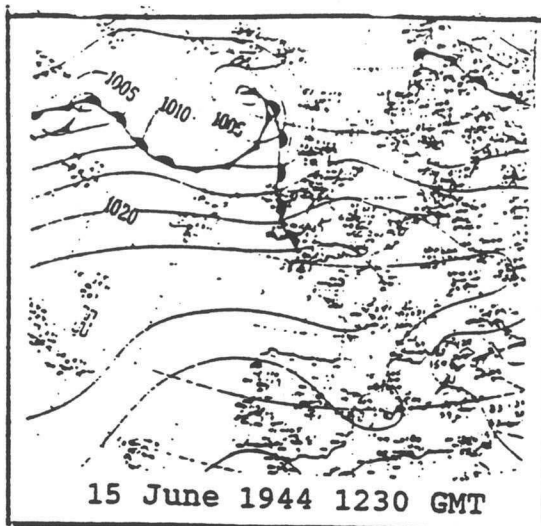


Fig. 2

Sequence of charts showing the development of rough seas on the Normandy beaches for several days beginning on 19 June 1944.

** NOTES **

- [1] Many uses of aerial photographic reconnaissance are well known. Particular in support of D-Day, however, were the photographs taken at wave top height, three to four miles out from the coast, to provide coxswains with a landing craft view of the particular area to be assaulted or likely to be their allotted landing spots. Other photographs were taken at zero feet 1500 yards from the coast to provide platoon commanders with recognition landing points. In the two weeks prior to D-Day, one RAF Mobile Field Photographic Section alone made more than 120,000 prints to meet Army requirements. (Air Chief Marshal Leigh-Mallory's Despatch, p.51).

A comprehensive and readable account of the relationship between meteorology and aerial photographic reconnaissance is given by Cowling (1987). On photographic reconnaissance generally, he commends *Evidence in Camera* by Constance Babington-Smith.

- [2] Personal accounts of the provision of METEOR winds for artillery and of the meteorological involvement in the development of FIDO and in forecasting for its operation are given by Ogden (1987 and 1988). British meteorologists began to provide the Royal Artillery with upper wind information in 1915: a following "wind of 20 miles per hour can take a shell 300 yards beyond the target it would reach in still air."

Fog clearance by heat had first been considered as early as 1921. The first landing in fog was made by Group Captain, later Air Vice-Marshal, D C T ("Pathfinder") Bennett. Between 1943 and 8 May 1945, FIDO cleared fog on 161 occasions and allowed about 2500 aircraft to land, 722 of them in fog.

Personal reminiscences of smoke screen work are also

given by Ogden (1985). The first trial was on 20 June 1940 and by 1942 over 30 sites were protected. A great deal was learned about local drainage winds.

- [3] As a consequence all taking part in the crucial decision as to when to launch D-Day were at least weather conscious. In his *Despatch*, (p.63, paragraph 259) Air Chief Marshal Leigh-Mallory wrote:

"...the Allied air forces succeeded in crippling one of the most dense and complex networks of railways and roads in the world, and in practically denying its use to the enemy. I must emphasize, however, the influence which bad weather had on these operations. Both heavy and medium bombers, because of this bad weather, were prevented time and time again from taking part in planned attacks on railways and bridges. We needed weather consistently good enough to permit precision visual bombing in density and co-ordinated attacks of a type most appropriate, as regards aircraft and weapons, to the targets involved throughout the whole of this period. I am convinced that if we had had this weather the enemy would have been prevented from moving by rail at all, and his retreat, disastrous as it was for him, would have been virtually impossible and far more costly in casualties to personnel and equipment than it was."

- [4] The Gloster Gladiator last flew in its meteorological role in March 1945. Pearcey (1989) reviews their role and that of the other meteorological reconnaissance aircraft from an aviation point of view fairly comprehensively. AP 1134 (pp.87, 88, 279, 344, 386, 401, 414, 415, 484 & 485 (instruments), 564 & 565 (observers) and Appendix 1) deals with organizational aspects. See

also Rackliff (1987). The data from these flights still represent a unique body of information, combining eye observations of cloud with profiles of temperature, pressure and humidity: they were still being used in the Met. Office's Special Investigations Branch well into the 1960s.

- [5] Oral tradition has had it that when Allied and German meteorological reconnaissance aircraft met they metaphorically raised their hats to one another and went on about their business. Bundgaard (Fort Ord p.14) writes

In many respects, as far as weather was concerned, World War II warfare support was rather agonistic, being carried out and fought according to special game rules. This was especially true in the weather field because of the past international character of meteorology. For example, almost daily, the Luftwaffe weather reconnaissance out of Brest and the R.A.F. Lancasters out of St Mawgan, in Lands End, would meet over the water and rendezvous in the Biscay area, saluting one another with wing dips. And those allied planes maintaining surveillance over the two German weather subs were carefully instructed, I was told, not to bomb them. Due to an error, however, one did. And, the next day or so thereafter, in retaliation, one of the allied weather ships was torpedoed and sunk by the Germans.

This international brotherhood is very fine and is the very rock on which peacetime meteorology is built. It is in each nation's interest that its meteorologists work in harmony with those of other countries. During World War II, however, meteorologists on both sides were loyal to



Figure 3. Routes used by Luftwaffe meteorological reconnaissance aircraft

their compatriots and did their duty; there was, sadly, realism behind the chivalry:

on the German side, the desperate shortage of weather information over the Atlantic meant it was wise to placate any threat to gathering it, (see [7] below) and,

on the Allied side, the observations made by the Germans were quickly received in the main Allied meteorological centres through intelligence channels. See 2.7 above.

A chatty review of meteorological reconnaissance flights, much of it based on personal experience is given by Rackliff (1987). This article includes details of the codes used to send weather information back to ETA, and so the range and degree of detail of information reported. *Inter alia* he refers to an account of the long history of co-operation between the Royal Flying Corps (and later the Royal Air Force) by Group Captain the Reverend Alec Haslam MC DFC.

[6] An account of the organization of the Office during the war is given in *Air Ministry, M.O.M. 475*. A copy is at Annex A. The scheme of equivalent ranks was first promulgated in Air Ministry Order 529/42.

[7] *The "Bulletin" Interviews* (1988) p.140 contains a German weather chart for 14 January 1945 which has observations plotted for three stations in SW England and one in Pembrokeshire.

Post-war interrogations of Luftwaffe meteorologists (Air Ministry/USAFE 1946, pp.39&40) showed that the most successful and reliable sources of information available to the Germans were their own meteorological

reconnaissance aircraft. A map showing typical routes is at Figure 3. Reports from agents were not very satisfactory. The Germans also had a listening-in and deciphering service. Weather reports passed to Allied aircraft, especially bombers returning from missions, gave very useful indications of weather over England and forecasts were also sometimes picked up. Instructions to Allied pilots to divert gave indications of areas where the weather was unfavorable and where it was better. Control messages on the ferry route between America and Europe were also regularly deciphered, including routine values of surface atmospheric pressure, QFF. Attempts to break the enciphered routine broadcasts of synoptic data, however, had only very insignificant success.

[8] Hinsley, Thomas et al. (1988, p.125) say that

"SHAEF's weather forecasts were derived primarily from reports sent in by US and British ships from pre-determined positions in the Atlantic. There is no substance in the claim that the decrypts of German meteorological reports contributed significantly to their accuracy."

Without underestimating the importance of the special weather ships in data-sparse 1944, meteorologists will know that reality is not as simple as this assessment by Hinsley, Thomas et al. Forecasts are based on an analysis of the whole chart and a substantial part of the area on the charts for early June 1944 is covered with reports from occupied and neutral Europe obtained through intelligence sources. A good deal of detail on how the data were obtained is given by Lewis (1985).

Data were available for both surface and upper air charts: by 1944 both sides had begun to map the upper air, to forecast flow patterns there and have some

understanding of the four dimensional dynamics of the atmosphere. At the Central forecasting Office at Dunstable there was a separate upper air unit. "The upper air forecaster routinely discussed probable synoptic developments with Pettersen before SHAEF conferences and Sverre (Petterssen) frequently attempted to give the general synoptic development several days ahead based on upper air patterns." (RAS Ratcliffe, upper air forecaster at Dunstable in June 1944, private communication.) An excellent review which gives the feel and scope of weather forecasting in this period is given by Gold (1947). This includes a 500mb chart for 3 June 1944 at 0600. Thinking on the development of synoptic systems, as recorded by Sutcliffe (1947) and Sutcliffe and Forsdyke (1950) was confined to a few specialists at main upper air forecasting centres. (A non-technical account of some progress in meteorology during the war is given by Poulter (1945)).

Hinsley, Thomas et al. go on

"On the contrary, the German meteorological service, crippled by the loss of its outlying stations in Greenland, Spitzbergen, Iceland and Jan Mayen and reduced to dependence on reports from a mere two or three U-boats in the Atlantic and daily meteorological flights to the west of Ireland, was unable to provide the forecast of the short-lived break in the bad weather that enabled Eisenhower to make his decision. Had it been otherwise, moreover, it must be regarded as highly improbable that the Germans would have been influenced by such a forecast. As C-in-C West had stated in his appreciation of 8 May, their basic assumption was that the Allies would attempt to land when they were sure of a 'series of days of continuous fine weather'".

It is clear that the problem on the German side was not the failure of the meteorologists (even though they were working in trying circumstances), but the belief of the German Army (and Navy (Zimmerman, p.185) who formulated the criteria used by the meteorologists) that the Allies would not attack without several days of light winds. Flohn (*Fort Ord*, p.95) says the German meteorologists could not afterwards find that their two or three day forecast was substantially wrong. In view of the force 4 and 5 winds the Allies experienced during the crossing this seems a fair assessment.

[9] These four criteria a., b., c. and d. are given in *Meteorological Implications*. Freeman (p.203) gives the conclusions of the Principal Staff Officers of the Joint Commanders-in-Chief for clouds as:

"not more than half overcast below 5,000 feet and cloud ceiling not lower than 11,000 feet.

By night lower cloud conditions would not seriously hamper operations and in general a lower standard of weather is acceptable for full scale operations by heavy bombers."

The differences between these Principal Staff Officers' criteria and those in *Meteorological Implications* are significant for visual bombing just inland of the invading troops. On the basis of the meteorological briefing, at the 2130 meeting on Sunday 4 June Tedder and Leigh-Mallory expected a reduced ability to carry out visual bombing on 6th. Nevertheless Hinsley, Thomas et al. regard the medium level cloud on 6th as a failure in the weather forecast. (See [32] below.) The need for absence of cloud below 11,000 feet would have raised the

odds quoted in section 3.4 even further. In practical terms the invasion would never have taken place if the meteorologists had not emphasized the improvement expected on 6 June and General Eisenhower had not decided to make the best of what it looked as though he would have, below agreed minima or not.

[10] Membership: Chairman, Professor S Chapman MA DSc FRS; Vice-Chairman, Mr G M B Dobson MA DSc FRS; Members, Professor D Brunt, MA ScD FRS, Professor Sir Geoffrey Taylor MA ScD FRS, Director of the Meteorological Office. The Committee reported to the Secretary of State for Air. See Annex A.

[11] The members included E G Bilham, C E P Brooks, E Gold, A H R Goldie, Inst. Cmmdr C T Suthons RN and Sir Gilbert Walker (MRP 136).

Commander Suthons also produced a guide for Naval Meteorological Officers relating the period and height of sea waves to wind speed and fetch. He did this in time for Operation Torch. His method was also used for Operation NEPTUNE. (See [22] below, Charnock (1987), *The forecasting of sea and swell waves*, Naval Meteorological Branch Memo. 135/45, 1945, and *Wind, Sea and Swell: Theory of Relations for Forecasting*, H U Sverdrup and WH Monk, HO Pub. No. 601, US Hydrographic Office, Technical Report, Number 1, 1947.)

[12] See, for example, Meteorological Research Papers 27, 35, 57, 66, 80, 81 Item II5, 82, 97, 118, 123, 125, 125a, 133, 134, 135, 136, 172 Item II6, 173 para 7c, 175, 181, 182, 216 para 7c. They report on the progress of wartime investigations into what is now called medium-range forecasting. Copies are available in the National Meteorological Library, Bracknell.

- [12a] An account of life in the Met. Office at Stonehouse during World War II is given by Lewis (1986) and of the Instruments Branch there by Scrase (1947).
- [13] Dr R C Sutcliffe, meteorologist at HQ Allied Air C-in-C, leading research worker on the three dimensional dynamical behaviour of the atmosphere and participant in the SHAEF telephone conferences in the run up to D-Day, has written "In common with some others I thought Krick's system of analogue forecasting, what I knew of it, could be no basis for forecasting but, then, we had at the time no methodology for prediction beyond a day or two, the extent of simple extrapolation of current trends and general judgment. Any plausible evolution was more or less as convincing as any other and there was enough experience and talent available to ensure that the predictions were at least reasonable. Actually it was the skill in short range forecasting which finally carried the day and there was no one better than C K M Douglas [13a] in that speciality. Petterssen was a real source of strength giving a beneficial theoretical and scientific stiffening to the British team... " (Fort Ord, 1984, page 99). See also the exchange between Krick and G D Robinson forty years on in *Fort Ord*, p.108.

Freeman (paragraph 100) summarizes the received wisdom used in the planning phase:

"Neither forecasting skill nor the law of averages could give any reasonable assurance of fine weather on or after D plus 3. Thus, unless adequate provision were made in the plan to meet the possibility of a break in the weather on D plus 3, the operation would be a mere gamble on the chances of the weather."

- [13a] CKM Douglas OBE AFC MA (1893-1982). Like Stagg a Scot.

Senior forecaster at ETA for many years and later the Assistant Director of the Meteorological Office responsible for Central Forecasting. Colleagues talk of his legendary memory for weather situations and his skill as a forecaster, backed up by cogent physical argument. "The greatest forecaster of his generation in the United Kingdom and quite possibly of all time." Like the other forecasters who contributed to the telephone conferences which led to the forecasts for D-Day, he received a personal letter of thanks from General Eisenhower. A note on his retirement is in the *Meteorological Magazine*, 83, 1954, p.225: obituaries are in the same journal for 1982, p.252 and in the *Quarterly Journal of the Royal Meteorological Society*, 1982, p.996.

Concerning the D-Day forecasts, he wrote that Eisenhower "regarded the meteorological advice received as supplying adequate grounds for going ahead, having regard to all the other factors. If the forecasters had played for safety too much and introduced a pessimistic bias into their forecasts, the vital decision of the Supreme Commander would have been made more difficult, or even prevented altogether." (Douglas, 1952).

- [14] Harrison, p.276, note 19, comments, on the basis of *Beitrag zur Frage der Landemoglichkeiten an der Kueste des Kanals, 1 Jan 1944. Seekriegsleitung/ 1 Abt., KTB Anlagen 1.I.-30.VI.44*: "the German Navy view was that at least five consecutive days of favorable weather would be necessary for the success of the landings."

- [15] James Martin Stagg CB OBE DSc FRSE (1900-1975). President of the Royal Meteorological Society 1959-1961. Entered the Meteorological Office 1924 as Professional Assistant. Led the British Polar Year Expedition in arctic Canada 1932-1933. Superintendent of Kew

Observatory from 1939.

In November/December 1943, Stagg spent a month in the Mediterranean with P J Meade, Chief Meteorological Officer there, learning the meteorological and organizational lessons drawn from invasions in that theatre. On one occasion Stagg, Meade and Generals Alan Brooke (Chief of the Imperial General Staff) and Mopntgomery were simultaneously in no man's land in Italy ahead of the Allied infantry! In recounting this and other matters, Meade (1987) puts anecdotal flesh on the bare account in AP1134 of the meteorological aspects of operation Torch and follow-up operations.

Stagg was authorized to wear the uniform of a Group Captain in the Royal Air Force from 4 February 1944 but not mobilized into the Royal Air Force Volunteer Reserve until 18 April 1944. His being a civilian was a matter of some concern to the US military who were unaccustomed to civilians as staff officers. (See 2.5.1 and [6] above, and Stagg (1971), p.35 et seq.)

His not being a forecaster was of concern to some meteorologists at the three centres who knew well the pressures on operational forecasters of the weight of decision on the basis of insufficient and inconclusive evidence. Stagg, although ten years younger than Eisenhower, was, however, already a meteorologist and geophysicist of some distinction and mature judgement. He subsequently rose to become Deputy Director-General and Director of Services of the Meteorological Office. Note on retirement by Sir Graham Sutton in *Meteorological Magazine*, Vol.89, 1960 p.222. Obituary by Dr R C Sutcliffe in *Quarterly Journal of the Royal Meteorological Society*, 1976.

Commander in Chief of the Allied Expeditionary Force, whose headquarters at Southwick House, near Portsmouth, were Eisenhower's Forward Headquarters in the days before D-Day. Later Instructor Rear-Admiral Sir John Fleming KBE DSC (Chalmers, p.206 note 1, and Who's Who for 1994). The Air C-in-C, Leigh-Mallory (Despatch, paragraph 186), saw Stagg, Yates and Fleming as representing the Air, Army and Naval Meteorological Services.

- [17] The wooden-hutted Central Forecasting Office and communications centre for the Met. Office, known in wartime as ETA, was first occupied as Emergency Temporary Accommodation in February 1940, following a short-lived move from the Air Ministry, Kingsway, to Birmingham in August 1939. Dunstable remained the forecast and communications centre until the Office brought most of its headquarters functions together in Bracknell in 1961.

An account of wartime life in the Central Forecast Office at Dunstable is given by Bilham (1947) and of the SFERICS (thunderstorm location system) there by Ockenden (1947). For at least some of the war the huts were covered with camouflage netting (Thelma Gadsden - personal communication).

- [18] Southwick House, near Portsmouth, became the home of the Royal Navy's Navigation School between 22 May and 27 September 1941. It was an imposing but completely unmodernized Victorian mansion standing in a park of some 300 acres. Its history as HMS Dryad is given by Schofield (p.67). The library became part of the wardroom mess. The selection and adaptation of Southwick House as Forward Headquarters for the Supreme Commander and HQ of Allied Naval C-in-C is recounted by Schofield (pp.79 & 80). A prime requirement was ample tree cover for the tents and caravans of 21 Army Group HQ and the SHAEF Forward HQ. Admiral Ramsay moved in on 26 April

and Eisenhower and Montgomery and their staffs three weeks later.

- [19] See [13] above and Fort Ord (1984), especially pages 106-110 and exchanges between Krick and G D Robinson, including Robinson's assessment that, despite Stagg's and Yates' opinion soon after D-Day, perhaps a better forecast was arrived at by involving several centres that could have been done by any one centre.

Ensuring coherent forecasts from forecasting centres of the RAF and USAAF had arisen before in Italy (Meade). In March 1944, the US Principal Forecast Office and the RAF Central Forecasting Office worked in offices in Caserta which were located side by side. It was considered that initially different technical procedures would make a single integrated office inefficient for too long a time.

- [20] 1930 GMT. In most of the documents relating to D-Day the times quoted are Double British Summer Time, two hours ahead of Greenwich Mean Time. There is, however, room for uncertainty sometimes when the time standard is not stated. On 6 June the start of nautical twilight (sun 12 degrees below the horizon) was 0406 GMT, 0606 DBST. H hour was 0630 DBST as the earliest on the Western Task Force front and 0745 for the latest group of Force "J" in the east. (*Battle Summary*, p.24).

- [21] The first V1s fell on London during the night of 12-13 June 1944 (Churchill, p.17). W D May (in a recorded interview on 12 May 1994) recalled seeing V1s air-launched from Dornier bombers off the Essex coast whilst he was serving in the meteorological office at Bradwell Bay in about September 1944.

- [22] Drs Jerome Namias and Harry Wexler advised on this, using retrospective analyses of the circulation over much

of the northern hemisphere. Their results encouraged the idea that medium-range forecasting could also be useful for Overlord. For the state of sea they used techniques developed by Sverdrup and Munk that depended on estimates of the wind over the North Atlantic for several days previously. (*The "Bulletin" Interviews*, p.386.)

An authoritative account of Sea and Swell Forecasting for Operational Planning during the Second World War is given by Charnock (1987). He mentions that in November the Atlantic coast of Morocco climatologically has waves more than six feet high two days in three.

In 1948, Eisenhower wrote (*Crusade in Europe*, pages 108 and 109, based on

i. a *Diary, Office of the Commander in Chief*, kept on Eisenhower's instructions by Harry C Butcher and deposited in the Adjutant General's Office, US Department of the Army, and

ii. *Allied Force Headquarters, Commander-in-Chief's Dispatch.*):

"In the original planning the probability of encountering impossible conditions at Casablanca was one of the factors that made me reluctant to commit the largest of our contingents to this particular operation. The danger of last-minute postponement at Casablanca was a lively one....

Even as late as the afternoon before the attack, the weather reports from one of our submarines in the Casablanca region were gloomy.....

At no time during the war did I experience a greater sense of relief than when, upon the

following morning, I received a meagre report to the effect that beach conditions were not too bad and the Casablanca landing was proceeding as planned. I said a prayer of thanksgiving; my greatest fear had been dissipated."

Even the Allied landings in the relatively sheltered Mediterranean suffered from wind-generated waves. Meade (1987) mentions that many craft making largely unopposed landings near Algiers had difficulty in reaching the places assigned to them because of Force 4 onshore winds.

Charnock (1987) gives a short account of the of the Anglo-US Swell Forecasting Section set up before D-Day to measure and forecast wave height and period. The Section set up 51 reporting stations along the south and southeast coast of England which reported wind speed and direction, and wave height and period.

The forecasts were apparently short-period "By midnight the Swell Forecast Section were predicting that by dawn the waves would be 3 to 4 feet high at the embarking and unloading zone offshore and peaking to 4 to 6 feet on the beaches before breaking. They expected a longshore current of one and a half knots and a rapidly rising tide. These conditions were thought difficult but manageable and the invasion went ahead. The wave forecast was good - the wave heights are reported as being within one foot - but the waves and currents led to considerable difficulty."

[23] In the Archives of the Meteorological Office are charts for 500mb and 300mb, as well as for the surface. At 1800GMT on 3 June 1944 there was a strong WSW'ly flow over the Atlantic at 500mb and 300mb. By 1800GMT on 4 June a deepening surface low south of Greenland was moving slowly NE and throwing up warm air on its eastern

flank leading to a developing 500mb and 300mb ridge. This upper ridge was south of Iceland by 1800GMT on 5 June and 0600 on 6 June.

A surface depression near Shetland had driven a cold front southeastwards across southern England to give strong winds and rain at Portsmouth during the critical briefing on the evening of 4 June and then on into France. This low filled and transferred southeastwards in the NW'ly thermal winds on the forward side of the upper ridge, to be over the southern North Sea during the 6 June.

The upper ridge moved east to be at 10-15 degrees west by 0600GMT on 7th with an upper high between Iceland and Norway, while the North Sea low and cold pool moved east into Germany only slowly. This small omega block moved slowly east with its ridge axis being at about 5 degrees west by 1800GMT on 8 June.

So, as a result of deep low moving slowly NE to the south of Greenland on 4th, there was a change of type in longitudes near the British Isles by 6th from a mobile W'ly to a temporary small block: the forecast on the evening of 4 June brilliantly identified a period of immunity from major storms. On the essential strategic scale the forecast was a very good one. See [32].

At the same time, the unforeseen, smaller-scale, slipping of the low from Shetland southeast into the North Sea maintained surface winds over the English Channel and the Normandy beaches which were somewhat stronger than forecast - typically Force 4 early in the day but Force 5 or 6 later on - and gave rather more deep cloud than expected over eastern France.

[24] This would have precluded Airborne operations had the

meetings on Saturday evening 3 June and the morning of 4 June confirmed June 5 as D-Day. At 0800 DBST on 6 June, when the sun was shining in Portsmouth, Eisenhower sent a TOP SECRET cable to General Marshall, noting:

"The weather yesterday which was the original date selected was impossible all along the target coast. Today conditions are vastly improved both by sea and air and we have the prospect of at least reasonably favorable weather for the next several days." (Chandler, p.1915)

- [25] Amongst the primary sources, Bedell Smith (1956), who was present, says Eisenhower said briskly "Well, we'll go!" Chester Wilmot in *The Struggle for Europe* (1952) has the general say "O.K., we'll go." and, according to Michie (1964), Eisenhower, during a 20th anniversary visit to Southwick House, confirmed that these were the words he used.

Leigh-Mallory, also present, quotes him as saying "Well, I'm quite positive we must give the order; the only question is whether we should meet again in the morning." (Freeman, p.212). Tedder (1966, p.546), an eye witness, and a secondary source Croswell (1991, p.243) also quote "I am quite positive that the order must be given". Croswell also adds "O.K. let's go."

The dangers of using journalistic, secondary, sources are exemplified by Michie (1964). He quotes "Okay, let her rip." (p.146). On p.195, though, he notes how, as a reporter for *The Reader's Digest* in the days immediately following D-Day, he had first proposed these words and then received Eisenhower's permission to use them as "an authorized quote. He also authorized the censor to pass the phrase".

An authoritative assessment by Ambrose (1969, p.417) quotes "O.K., let's go," on the basis of an interview with Eisenhower on October 27, 1967, when Eisenhower was sure that was what he had said. General of the Army Omar N Bradley (1971), in the Foreword to an authoritative review based on a 25th anniversary seminar on 6 and 7 June 1969, quotes "I'm quite positive we must give the order I don't like it, but there it is... I don't see how we can possibly do anything else." Bradley also makes the point that "No choice (of date) was clearly the best nor was any even clearly a good solution. As is true so often in matters of national consequence, each possible solution was fraught with unknowns." Reviews of contemporary sources for the meeting are given by Pogue (1954) and by Croswell (1991, p.398).

- [26] At the time of the conferences Schofield, later Vice Admiral B.B. Schofield CB CBE, was Captain of HMS Dryad, the "stone frigate" containing Admiral Ramsay's headquarters and the SHAEF Forward Headquarters.

Chalmers (p.217) quotes from Admiral Ramsay's diary for 1 June, two days before the "bloody nonsense" comment: "P.Vian (Commanding Eastern Task Force) has got an attack of quinsy, which is a most painful complaint I'm told...".

- [27] In his diary entry for Monday, June 5, 1944, Butcher (1946, p.482) notes the Deputy Supreme Commander, Air Chief Marshal Tedder, telling him that at the Sunday night meeting Stagg had been asked what the weather would be on D-Day in the Channel and over the French coast. "He hesitated, Tedder said, for two dramatic minutes and finally said, conscientiously and soberly, "To answer that question would make me a guesser, and not a meteorologist."" Butcher castigates this as "a refusal of the weather man to be a "guesser" and as leaving the

Supreme Commander to make the decision without satisfactory assurance from the meteorologist - "responsibility which Tedder said Ike took without hesitation."

Freeman's account of this meeting is based on notes kept by Air Vice-Marshal James M Robb, who was present as Deputy Chief of Staff Air. (On 14 May 1945, as Air Marshal Sir James M Robb, KBE, CB, DSO, DFC, AFC, he was appointed C-in-C Fighter Command Royal Air Force): she makes no mention of the "guesser" incident (Freeman, p.212). She does, however, quote the Supreme Commander and General Bedell Smith as being of the opinion after they had heard the meteorological briefing on the Sunday night that "we had "gotten a break that we could hardly hope for"". This is hardly consistent with Butcher's account, nor with the esteem in which Eisenhower apparently held his meteorological team: see Michie's comments in [37] below.

According to Air Chief Marshal Tedder himself, but writing twenty years later in 1966, it was at the meeting on Monday morning, at which the final decision became irrevocable, that Stagg, pressed for a forecast for a longer period, said "No! If I were to do that I would be a guesser and not a meteorologist." (Tedder, p.546).

Pogue (1954, p.170) summarizes the accounts of the two final meetings then available to him and does not mention the incident. Like Freeman, he had access to the report written on 5 June by Air Vice Marshal Robb, and statements by Eisenhower, Tedder, Creasey and Strong who were also present.

Bedell Smith (1956, p.54) also recounts his memories of the meetings, quoting detail of the briefing which is hardly consistent with Butcher's account.

Stagg's own account in *Forecast for Overlord* was based on his own diaries and was published in 1971. He gives a detailed account (pp.112-114) of the Sunday evening meeting, including details of the forecasts of cloud, visibility and wind for Tuesday 6 June. On pp. 116 to 118 he gives details of the meeting early on Monday morning and again quotes forecast values of cloud, visibility and wind for the assault. He makes no mention of the "guesser" incident, though in other respects the account agrees with other eye witness accounts.

There is no reason to doubt Tedder's (1966) report of the "guesser" incident, but it seems best to discard Butcher's hearsay, even though it was produced before memories became compacted. Stagg was a meteorologist and geophysicist who understood very well the nature of the atmosphere's behaviour as understood in 1944; although not trained as a forecaster he would know as a matter of course the results of the Meteorological Research Committee's investigations on forecasts beyond the first day or two. [27a]. See also [15] above.

Later, after the first landings had been made, Churchill told the House of Commons that "A very great degree of risk had to be taken in respect of the weather." (James, 1981).

[27a] It also happens that a copy of MRP 80 of 8th March 1943, taken into the Meteorological Office Library on 4 May 1943 and now in the National Meteorological Library, Bracknell, carries an annotation "Actual copy used by Dr. Stagg." The MRP concerns *Classification of Daily Weather Charts 1930-1941: Persistence and Movement of the Main High Pressure Systems*. The provenance of the annotation is not known.

[28] General Eisenhower would have also known the assessment by the intelligence staff (Hinsley, Thomas et al. p.63 and p.794) that the Germans considered "Allied preparations sufficiently advanced to permit of operations at any time now", that the invasion was "not far off" but that the Allies would attack only as soon as "a series of days of continuous fine weather" set in. An earlier analysis by Shirer (1960) suggests that the "German Army itself was beset by doubts, at least as to the date and place of the assault. In May there had been eighteen days when the weather, the sea and the tides were just right for a landing, and the Germans noted that General Eisenhower had not taken advantage of them."

[29] *Battle Summary* (page 75, footnote 1) notes that Admiral Ramsay remarked, after 6 June, that "although the unfavourable weather caused difficulties and damage to craft off the beaches later, the advantages gained by surprise were so striking that the decision of the Supreme Commander to go on despite the weather was amply justified." Similarly, on page 81, it notes "That the decision of the Supreme Commander to launch the assaults under such conditions was the correct one has never been questioned. An unfortunate doctrine had, however, been given full promulgation during planning, particularly in Army circles, namely that fine weather and a calm sea were essential for the assault. In retrospect, with the experience of Operation 'Husky' still fresh in our minds, and with the knowledge of the fickleness of the weather in the Channel, this should never have been allowed."

[30] German Naval experts had calculated that Allied landings would be possible only in seas with waves less than 5 to 8 feet high (Harrison, p.276)

[31] Lieutenant-General Bodo Zimmerman was Chief Operations

Officer to the German Commander-in-Chief West from 1940 to 1942 and of Army Group D from then until the surrender.

[32] Criticism of agreed forecast on 3 June for 5 June

Krick (*Fort Ord*, p.25) suggests that "the front had been clear over to Paris by the morning of the fifth and the winds in the Channel actually were less than they were at times on the sixth. So that we could have gone on the fifth" This takes no account of the early hour at which the assault on 5th would have had to take place. See also note [24] above.

Inspection of the charts plotted at ETA and now in the Meteorological Office's Archives shows that while the surface winds on the Normandy beaches were no less favourable on 5th, seas in the Channel would have still been rough (following moderate to strong winds during the previous few days which had a long WSW'ly fetch) and the clouds for bombing, reconnaissance and landing of airborne troops were much less favourable than at corresponding times on 6th: at 0100GMT (0300DBST - about 4 hours ahead of H hour and when airborne forces were planned to drop inland behind the beaches [32a]) the cold front extended from Eastbourne to Cherbourg to Brest. During the 24 hours of postponement it moved across the Normandy beaches, and airborne landing zones, and away some 300 NM southeast and slowed down. At 0100GMT on 6th it lay from extreme SW France to 44N 00 to 46.5N 05E to 50N10E. Showery weather on 6th, associated with the North Sea depression, hindered bombing of communications in northeast France, and so led to an imperfection in the execution of the overall plan; by contrast, the organized deep cloud of the cold front over the assault area itself at the relevant times on 5th would have totally precluded air support of the ground forces and the key operation of landing airborne troops behind the

beaches. Nor would the airborne troops have had the moonlight they preferred.

Criticism of forecast on 4 June for 6 June

Hinsley, Thomas et al. (p.131) suggest the weather was worse than had been forecast. See [23]. Two specific elements are said to have been wrong: Wind (and so sea), and Cloud.

i. Wind and Sea

"The run in, timed to be completed at varying H-hours between 0630 and 0755 (DBST - S.C.) at the five beaches, took place in weather that was worse than had been forecast, with steeper seas and stronger winds. Many of the smaller landing craft foundered during the crossing. On some of the beaches it was difficult to locate the pre-arranged landing places. Still more serious, the stiff on-shore wind had so raised the level of the tide that the underwater obstacles were already under water when the first landing craft arrived." This assessment is based on the history by Ellis (1962). Flohn (Fort Ord, p.95) says "there were gusty winds Bft. 5 or more and the losses were rather high." (Beaufort Force 5 = 19-24 m.p.h.) Admiral Ramsay's Despatch (paragraph 42) says "Weather conditions off the assault beaches immediately before H hour were as follows:-

Wind. - Westnorthwest - force 4*.

(*Moderate breeze 11-15 m.p.h.)

Sea. - Moderate - waves 3/4 feet.

Sky. - Fair to cloudy with cloud increasing."
[32b].

Battle Summary, section 51, quotes Rear-Admiral Hall, Naval Commander, Force "O", giving an account of the battle for "Omaha" beach:

"The weather was unfavourable but landings were possible. The sea was choppy, with wind force 5 from the SW. The sky was partially overcast with visibility about 10 miles...."

C K M Douglas was one of the two forecasters speaking for ETA on the D-Day telephone conferences and a revered figure with experience as a meteorologist in both World Wars; R A S Ratcliffe, in (Fort Ord, p.97) calls him "the greatest forecaster at the time". A H Gordon (Fort Ord, p.104) quotes Douglas as saying of 6 June

"The onshore wind was above the permissible limit previously laid down by the Admiralty and by all accounts must have been near the actual limit above which landings would have been impossible."

On the Allied side, many forecasts were issued, of course, by different meteorological offices to many different levels of command. However, *Meteorological implications*, pp.9&10 (Annex B), gives the forecast made by Stagg to the Supreme Commander and the Commanders in Chief in the evening of Sunday 4 June. As a source it has the merit that it was a report prepared by the people who made the statement to those who heard it and so would criticize it if it was inaccurate. "Wind speeds by Monday evening should decrease to Force 3-4 on the French Channel coasts... Wind will be mainly Force 4 on the English Channel coast and Force 3-4 on French Channel coasts; in sheltered stretches of the French Channel coast periods of Force 2-3 could be expected. The direction throughout will be Westerly". In the event, over the Channel throughout the 6th "a gradient of 25-30 mph. from the northwest was maintained." (*Meteorological Implications*, p.24.) Such a gradient wind might typically be expected to give surface winds over the open sea of 15-25 mph from the WNW, a fresh breeze and rather more

than the "quiet day" specified as necessary on p.3. Inland over France, for the airborne forces' landings during the night and early morning, wind speeds with this gradient would be expected to be rather less than half these values and so well below the Army's upper limit for paratroops of 20mph (p.2). On the other hand, the naval requirement was that surface winds should not exceed Force 3 (8-12 mph) on shore or Force 4 (13-18 mph) off shore in the assault area; winds might be Force 5 (19-24 mph) in the open sea for limited periods (p.2). See also [8] and [23] above.

ii. Cloud

Hinsley, Thomas et al. (p.132) also judge, from AIR files in the Public Record Office, that while the achievement of tactical surprise was due to the adverse weather, the weather "went far to reduce the ability of the Allies to exploit the advantages of surprise or the offensive benefits they might have derived from air power in the critical period following the landings. While fighters could operate defensively in the overcast weather that prevailed till the afternoon, the heavy bombers were severely handicapped in implementing 'carefully laid plans to stop enemy movement by demolishing towns to block main roads'. 500 bombers which set out to attack eight key road centres had to return without bombing." "..... the poor weather almost eliminated the work of the PR squadrons on D-Day." ".... it was these two consequences of the unseasonable weather which prevented any of the assault forces from gaining its D-Day objectives and which, in particular, frustrated the Allies in their central purpose, the rapid capture of Caen." This is consistent with the assessment by the Allied Air C-in-C's Despatch (Leigh-Mallory, 1947, paragraph 406: "In making the Assault, despite the bad weather, there is no doubt that the invasion forces won an increased chance of tactical surprise."

Freeman includes the Minutes of the Allied Chiefs of Staff and their senior officers held at Southwick House on 29 May 1944: "the Air Forces were examining modifications in existing plans which would be necessary in the event that the assault is carried out in bad weather conditions." At an Allied Air Commanders' meeting at 1100 DBST on Saturday 3 June the Allied Air C-in-C said that "it was quite possible that the operation might take place in conditions that were very far from ideal from an air point of view, but in that case the Army were warned to expect less support from the air." (Freeman, Appendix VI/122, Minute 12).

At the Sunday 4 June evening conference at Southwick House, Tedder agreed with Leigh-Mallory that "operations of the heavy and medium bombers were going to be chancey". (Tedder, p.545; Freeman, p.212).

At 1100 DBST on 6 June, R C Sutcliffe briefed the Sixth Allied Air Commanders' Conference. As usual, as the meteorologist he made the first presentation. Sutcliffe "reported that the deep depression centred to the north of Scotland was filling up; clouds were still patchy over the target area, from 3/10ths to 7/10ths, with bases down to 2000 and tops at 8000. There was a chance of the clouds breaking later in the day, but no cloud dispersal could be confidently predicted at present." (Freeman, Appendix VI/175). At the same meeting, General Doolittle said that "the Eighth Air Force had already flown some 1,870 sorties, but that bombing had been entirely through overcast, and was therefore erratic."

Observations

Readers armed with a magnifying glass may compare these criticisms of the forecasts of wind and cloud with the

the Channel. Ramsay (1947) refers to the "north-easterly gale, unexpected and unforecast". Dr Lawrence Hogben, one of the Admiralty weather forecasters who took part in the pre-D-Day telephone conferences, in a private communication writes that "We were all wrong for the 19th, forecasting a calm anticyclonic period. We foresaw neither the wind force nor its effect on the Mulberries."

Freeman (Appendix VI/155) reports a meteorological briefing of the Allied Air Commanders Conference at 1100DBST on Tuesday 20 June by Colonel Spencer. There is no mention of strong winds in the Channel. The Naval Report said that "the Navy's chief trouble was the North-East wind. There was a 6 ft. sea yesterday, and sailings had been suspended. "Mulberry Whales" which had started on the promise of good weather were having a rough time; some were lying to off the Sussex coast; others had been lost on the way across. "Whales" in position on "Mulberry/A" had also been damaged."

Douglas (1952), as well informed on forecasting matters as anyone, (see [13a] above), intimately involved with forecasting for D-Day and with real-time access to all available information wrote "The development of June 19-20 was not forecast on the 18th, and it is difficult to see in retrospect how it could have been. Still less would it have been possible to foresee it in the early morning of the 17th when the decision to start the assault would have been made if it had been postponed for the 6th. After mid-June prolonged NE to E winds of force 6 or above are almost unknown. There were strong NE winds in early June 1939, but their onset was not sudden and there has been no other such spell in June during the present century."

[37] On 22 June the SHAEF Meteorological Section completed a report on the *Meteorological Implications in the*

Selection of the Day for the Allied Invasion of France June 1944. G D Robinson (Fort Ord, p.100), who remained in the SHAEF Meteorological Office whilst Staggs and Yates were at Southwick House and was the only person to take part in all the weather telephone conferences between 1 and 6 June, writes that the report is based on his notes made during those conferences. "Staggs edited out the more intemperate sections." The charts were drawn before June 10 and after June 6: "no one at the time could come up with a better guess". Staggs sent the report to Eisenhower, with a memorandum commenting that if he had delayed NEPTUNE by two weeks (which, because of the tides, he would have to have done if on June 4/5 he had decided to postpone) he would have run into the worst weather in the Channel for 20 years. Eisenhower wrote across the bottom of the memorandum "Thanks, and thank the gods of war we went when we did." (Chandler, p.1948). According to Michie (1964, p.195)

"Years later, the performance of his weathermen continued to impress General Eisenhower. At the late President Kennedy's inaugural, the ex-President and the President-to-be fell to chatting about D-Day as they sat upon the stand. Eisenhower explained that one of the Allies' great advantages in the invasion had been the skill of their weather experts."

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123. *Dr Brooks' Method of Pressure Wave Analysis*
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125. *Draft Report on the Trial of Symmetry Points and Pressure Waves as a method of Long Range Forecasting by J Wadsworth (7 August 1943; MRP 125a (Part III of MRP 125) 26 August 1943)*
133. *Report on the Work of the L.R.F. Unit, May to August, 1943 (26 August 1943)*
134. *Assessments by M.O.2(A) of Forecasts Issued by L.R.F. Unit (New Series) (27 August 1943)*
135. *A Periodogram suitable for use in Forecasting by Pressure Waves by C E P Brooks and N Carruthers (26 August 1943)*
136. *Sub-Committee on Long-Range Forecasting. Report of Meeting at Victory House on Wednesday September 1, 1943. (9 September 1943)*
175. *A Statistical Examination of the Results of Trial Trend Forecasts during the period September 1943 - March 1944 by C E P Brooks (21 April 1944)*
181. *Report on the methods and results of medium-range forecasting based on pressure waves by Miss N Carruthers (21 April 1944)*
182. *Report on the Qualitative Assessment of Trend Forecasts prepared by Dr Brooks during the period 17th September, 1943 to 20th March, 1944 by E G Bilham and C K M Douglas (21 April 1944)*

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ORGANISATION OF THE METEOROLOGICAL OFFICE, AIR MINISTRY, IN WAR

I. HEADQUARTERS ORGANISATION

GENERAL

1. The Meteorological Office is the State Meteorological Service. It forms part of the Air Ministry, the Director being responsible to the Secretary of State for Air through the Permanent Under-Secretary of State.

2. The general functions of the Meteorological Office are:-

- (1) Provision of meteorological services for the Army, Royal Air Force and Civil Aviation.
- (2) Liaison with the Naval Meteorological Service.
- (3) Meteorological services for Government Departments, local authorities and the general public.
- (4) Organisation of meteorological observations in Great Britain and Northern Ireland.
- (5) Collection, publication and distribution of meteorological information from all parts of the world.
- (6) Organisation and distribution of magnetic and seismological information from certain British Observatories.
- (7) Research in meteorological and geophysical subjects.

DIRECTORATE

3. The Director of the Meteorological Office is assisted by a Deputy Director and five Assistant Directors. Under the Assistant Directors there are numbered branches (M.O.1, M.O.3 etc.). The functions of branches are set out in detail later.

4. The Deputy Director is in charge, under the Director, of those sections of the office immediately concerned with synoptic meteorology and the supply of weather forecasts to the Services, Civil Aviation and other Government Departments. Under the Deputy Director are three Assistant Directors: - (Forecasting), (Home and Overseas). The Investigations Branch (M.O.9) and the section responsible for cyphers and security arrangements (M.O.15 (Security)) are also responsible to the Deputy Director.

5. The Assistant Director (Forecasting) is responsible for the Central Forecasting Office, the collection and distribution of synoptic data, the issue of basic forecasts, and investigation and research into technical problems of weather forecasting. He controls M.O.2, M.O.11 and M.O.12.

6. The Assistant Director (Home) controls M.O.6, M.O.8 and M.O.14 and is broadly responsible for meeting the meteorological requirements of the Royal Air Force at Home (other than Coastal and Transport Commands) and of the Royal Air Force and British Army with the Allied Expeditionary Force (N.W. Europe), the Ministries of Aircraft Production, Home Security, Supply and Fuel and Power.

7. The Assistant Director (Overseas) is responsible for satisfying the meteorological requirements of Coastal and Transport Commands and of the Royal Air Force and Army overseas and of Civil Aviation. He controls M.O.5, M.O.7 and M.O.6.

8. The other two Assistant Directors: (Climatology and Instruments) and (Personnel) are responsible direct to D.M.O., as is also the Superintendent of the Observatory.

9. The Assistant Director (Climatology and Instruments) is responsible for: Marine Meteorology (M.O.1), British and World climatological matters (M.O.3) and the provision and design of meteorological instruments (M.O.4). The Assistant Director has also certain administrative and technical responsibilities in connection with the Meteorological Research Committee and with problems referred to the Office by the Aeronautical Research Committee.

10. The Assistant Director (Personnel) is responsible for the recruiting and training of staff for the Meteorological Office, for personnel questions generally and for publications and for works services.

11. The Superintendent of New Observatory is responsible for the work on atmospheric electricity, meteorology, magnetism and seismology at the Observatories at New, Eskdalemuir, Aberdeen and Lorrwick. He administers the Branch Meteorological Office, Edinburgh, and is also responsible in collaboration with M.O.4, for the design of radio-sonic apparatus.

12. The Branches are in immediate charge of Principal Technical Officers.

The above organisation is set out diagrammatically on the opposite page.

BRANCH FUNCTIONS

13. M.O.1 - Marine meteorology, organisation of observations on ships; control of Port Meteorological Offices and Merchant Navy Agencies; compilation of marine meteorological charts and atlases, revision of Admiralty Pilots and Sailing Directions.
14. M.O.2 (Central Forecasting Office). - Manipulation and analysis of synoptic data. Preparation of weather forecasts.
15. M.O.3 - British and world climatology. Library. Special climatological investigations. Monthly Weather Report. Publication of "British Rainfall". Preparation of Naval Handbooks. Revision of meteorological sections of Admiralty Pilots. Collection and analysis of upper air statistics.
16. M.O.4 - Design and provision of meteorological equipment for Meteorological Office stations, the Naval Meteorological Service and the Merchant Navy, the Royal Air Force, the Army and other Government Departments.
17. M.O.5 - Meteorological requirements of the Royal Air Force in the West Indies, Bermuda, West Africa, Mediterranean Allied Air Forces, Middle East (including Aden, Iraq, Persia and East Africa) and Air C.S.E.A. Liaison with Colonial Office on meteorological arrangements in Colonies.
18. M.O.6 - Meteorological requirements of Bomber Command.
19. M.O.7 - Meteorological requirements of Transport Command and of Civil Aviation. Liaison with M.O.5 in respect of Transport Command requirements overseas.
20. M.O.8 - Meteorological requirements of Fighter Command, the Royal Air Force and British Army with the Allied Expeditionary Force (N.W. Europe), Anti-Aircraft Command and Ministry of Supply. Meteorological arrangements for Combined Operations.
21. M.O.9 - Preparation, in collaboration with M.O.1 and M.O.3, of technical reports and memoranda on special subjects. The branch deals, in particular, with demands for information which:
 - (a) require quick personal consultation in London;
 - (b) are of a semi-synoptic nature;
 - (c) relate to proposed sites for aerodromes;
 - (d) involve the preparation of "Aviation Meteorological Reports".
22. M.O.10(a) - Meteorological personnel (service and civilian): requirements, training, commissioning, promotion and personal status.
23. M.O.10(b) - Meteorological personnel (service and civilian): postings, records, civilian pay, allowances, removals etc. War emergency procedure.
24. M.O.10(c) - Meteorological Office financial estimates, cash and accounting. Publications, forms and stationery services. Accommodation and works services. Enquiries and general non-technical questions. Issue of M.O. Order etc.
25. M.O.11 - Collection and distribution of synoptic data and forecasts. (See Section VIII). Preparation and distribution of printed Daily Weather Report. General administration of the Assistant Directorate of Forecasting.

ANNEX H

26. M.O.11(a) - This is a section of M.O.11 which is responsible for liaison duties between M.O.2, M.O.11, M.O.12 and officers and Branches located elsewhere. It also maintains a continuous series of synoptic charts.

27. M.O.12 - (a) Current analysis of all the upper air data provided by the Meteorological Flights, radio-sonde and radio-wind stations (see Section XI). Provision of upper air forecasts. Development of improved technique in the use of upper air data and investigations on problems connected with the vertical structure of the atmosphere.

(b) Organisation of meteorological data from aircraft and control of radio sound stations in the United Kingdom. Development in collaboration with M.O.2 and New Observatory, of upper air technique.

28. M.O.13 - Meteorological requirements of Coastal Command (including Iceland, Azores, Gibraltar) and of the Royal Air Force in Northern Ireland.

29. M.O.14 - Meteorological requirements of Flying Training Command, Technical Training Command, Maintenance Command and Air Transport Auxiliary, Balloon Command, Ministries of Fuel and Power and of Aircraft Production. Meteorological aspects of short wave radio. General co-ordination of meteorological training in the Royal Air Force, preparation of meteorological instructional books, diagrams etc.

30. M.O.15 (Security) - General oversight of security arrangements; release of information to the Press and public; postal censorship; provision of cyphers (in conjunction with Air Ministry Signals Branch). Enemy intelligence.

TRAINING OF METEOROLOGICAL OFFICE STAFF

31. Training School. - A school for the training of forecasters and assistants is under the supervision of A.D.M.O.(P).

II. METEOROLOGICAL ORGANISATION FOR THE ROYAL AIR FORCE AT HOME AND IN N.W. EUROPE

32. The functions of the Headquarters Branches responsible for ascertaining the requirements of the Royal Air Force at home and administering the meteorological offices provided for meeting them have been set out in Section I. The Branches concerned are M.O.6., M.O.7., M.O.8., M.O.13 and M.O.14. This Section is therefore devoted to a description of the arrangements for supplying meteorological information to the Royal Air Force, U.S.A.A.F. and other Allied units in North-West Europe.

33. These arrangements fall into three main categories:-

- The Central Collecting, Distributing and Forecasting Office (M.O.2, M.O.11 and M.O.12).
- Branch Sections at the Headquarters of operational Commands of the R.A.F.
- Organisational Centres - Type 1 stations;
- Subsidiary Stations;

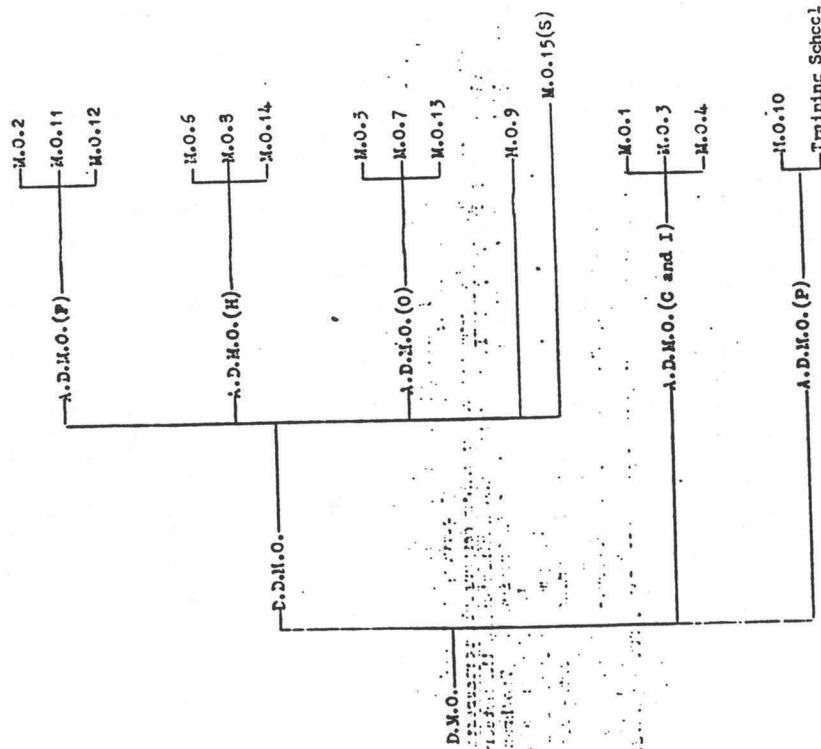
CENTRAL FORECASTING OFFICE

34. This is the Headquarters Forecasting Office of the Meteorological Office and is designed to meet the needs of all Departments and Services.

At this office the observations, British and foreign, are collected by telegram, telephone, teleprinter and W/T. They are distributed by teleprinter and W/T. Analyses, appreciations of the meteorological situation and forecasts are prepared and broadcast (see Section VIII), and serve to co-ordinate the meteorological advice given to the Services throughout the Home Commands.

ORGANISATIONAL CENTRES - TYPE 1 STATIONS

35. These stations are attached to Headquarters of Bomber, Fighter, Coastal and Transport Commands, to Group Headquarters in these Commands, to the Transatlantic Aircraft Control and to centres in certain Groups in Flying Training Command. Each Type 1 station is in the charge of a Principal or Senior Technical Officer who is Meteorological adviser to the Air Officer Commanding the Command or Group in question.



16. With the aid of synoptic charts and the general technical information issued by the Central Forecasting Office, Type 1 stations prepare forecasts and give advice to the Headquarters staff of the Command or Group. Their staff can give forecasts at once and at all times. There is frequent consultation between the meteorological staff at Command Headquarters and its dependent Group Headquarters.

17. A Type 1 station at Group Headquarters acts as "parent" to subsidiary meteorological offices (see paras. 19-42 and Section XIII) at Royal Air Force stations in the same Group. It performs a similar function for meteorological offices at certain stations of the Training Commands and at Ferry Pilots' Pools of the Air Transport Auxiliary which are conveniently situated geographically. It collects observations from these subsidiary stations and supplies them with information and forecasts. The Type 1 station at a Fighter Group Headquarters supplies forecasts to those Balloon Barrages under the control of the Group.

BRANCH SECTIONS

18. At the Headquarters of Bomber, Fighter, Coastal and Transport Commands there is a small civilian section of the appropriate Branch for the purpose of maintaining close liaison with the Royal Air Force and to facilitate the administration of the Meteorological Offices within the Command. The Principal Technical Officer in charge of the Branch divides his time between the Air Ministry and the Command.

FORECASTING STATIONS

19. These stations are of three classes, known as Type 2, 3 and 4 according to function. Stations of Types 3 and 4 are subordinate, generally to a Type 1 station, but in a few cases to a Type 2 station.

20. Type 2 stations resemble Type 1 stations to the extent that they have at least one independent forecaster qualified to provide forecasts, but the service provided is not necessarily continuous through the 24 hours. They are located at airfields such as stations of Coastal Command, Night Fighter stations and at certain Base Stations in Bomber Command which require a meteorological office of higher status than a Type 3 or 4. The staff brief aircrews before operations.

21. Type 3 meteorological offices, with dependent forecasters, are provided at operational airfields and Operational Training Units of Bomber Command, at Operational Training Units (and also some operational stations) of Coastal Command, at the Operational Training Units in Fighter Command, at Air Observer Schools and Advanced Flying Units of Flying Training Command, and at Ferry Pilots' Pools of the Air Transport Auxiliary. The staff obtain aviation forecasts from their "parent" Type 1 station and are qualified to explain and discuss the forecasts but do not, except in emergency, originate forecasts themselves. They brief aircrews before operations on the expected weather and supply written forecasts on Form 2330.

22. Type 4 meteorological offices are attached to Day Fighter stations of Fighter Command. The staff, as distinct from those of Type 3 stations, are assistants. Forecasts are obtained from the Type 1 station of the Group and the stations act generally as liaison units between the R.A.F. airfield staff and the Type 1 station. They obtain and distribute the information required by the R.A.F. units which they serve. The assistants explain the significance of technical terms used in forecasts and reports, but do not discuss the technical basis of forecasts.

III. METEOROLOGICAL ORGANISATION FOR THE ROYAL AIR FORCE OVERSEAS

(EXCEPT IN THE MIDDLE EAST AND CIVIL AVIATION)

23. Meteorological services are provided by the Meteorological Office, Air Ministry, in the following regions outside Great Britain:-

Bermuda
Iceland
Azores
Gibraltar

* See Section XIII for definitions of these terms.

WEST AFRICA

MEDITERRANEAN ALLIED AIR FORCES

MIDDLE EAST (including Egypt, Sudan, Abyssinia, Syria, Aden, Italian Somaliland, British East Africa, Palestine and Transjordan, Syria, Cyprus, Iraq and Persia).

SOUTH EAST ASIA

West Indies

24. In the cases of Abyssinia, Italian Somaliland, and the West Indies the services, although planned, have not yet been fully established. The remainder are all in existence.

25. Bermuda. - In October 1941, the Meteorological Service of Bermuda was placed under Air Ministry control for the duration of the war. The main forecasting station is concerned primarily with the mid-Atlantic route which runs U.S.A. - Bermuda - U.K. or U.S.A. - Bermuda - Lisbon (or Gibraltar), and also with the reinforcing route Canada (or U.S.A.) - Bermuda - Azores - N.W. Africa - India. Bermuda also forms an important reporting station for both naval and aviation purposes in the Atlantic.

26. Iceland. - 24-hour independent forecasting offices are maintained at Area Combined Headquarters for R.A.F. operational flights and at Reykjavik airfield for trans-Atlantic ferry and delivery flights. Subsidiary stations are maintained at other airfields, while liaison is maintained with the Icelandic Meteorological Service which continues to man its own reporting stations.

27. Azores. - 24-hour forecasting offices are maintained at Area Combined Headquarters for R.A.F. operational flights and at Lages airfield for transport Command ferry and reinforcing flights. Liaison is maintained with the Azores Meteorological Service.

28. Gibraltar. - A 24-hour forecasting service is provided to meet the operational requirements of Navy, Army and Air Force units and the requirements of aircraft in transit between U.K. and Africa.

29. West Africa. - The British West African Meteorological Service, which existed prior to the outbreak of war as a Colonial Government Service, was placed under Air Ministry control in April, 1941. A headquarters is maintained at Freetown and forecast units at Takoradi (Gold Coast), Bathurst (Gambia), Lagos, Kano, Maiduguri (Nigeria), and an interpreter (similar to Type 4 at home) station at Accra (Gold Coast). A network of observing stations is maintained in all four colonies and there is one at Monrovia (Liberia).

50. Mediterranean Allied Air Forces

(a) The meteorological services in N.W. Africa and the Central Mediterranean (including Malta) are co-ordinated by the Chief Meteorological Officer, M.A.F., M.A.A.F. who is responsible for meeting the meteorological requirements of the Army, the R.A.F. and the shore requirements of the Royal Navy in these areas. Close liaison is maintained with the U.S.A.A.F. Weather Service and with the French Meteorological Service. Control is also exercised over the Italian Meteorological Service in liberated areas.

(b) The meteorological organisation includes the following:-

- (i) A central forecasting unit which is responsible for the collection and dissemination of meteorological information throughout the area and for the exchange of meteorological data with adjacent areas.
- (ii) Forecasting units under senior meteorological officers at the headquarters of the main air forces.
- (iii) Subsidiary forecasting units at Group, Wing and Station Headquarters at Corps H.Q., and at the main transport Command staging posts.
- (iv) Forecasting or observing stations attached to survey regiments, mobile units to meet special requirements and at minor staging posts.

51. Middle East

(a) The meteorological services in the Middle East are co-ordinated by the Chief Meteorological Officer, H.Q., R.A.F., Middle East, who is responsible for

meeting the requirements of the Army and R.A.F. and the above requirements of the Royal Navy. Close liaison is maintained with the local services of Iraq and the Syrian Meteorological Service and with the local services of Iraq and the Syrian Meteorological Service and with the local services of Iraq and the Syrian Meteorological Service, both of which have been strengthened by the addition of Air Ministry meteorological staff.

(b) The British East African Meteorological Service was brought under Air Ministry control in January, 1941. It is now responsible for meeting the requirements of the R.A.F. and Navy in the East African area including the Western Indian Ocean.

(c) The Palestine Meteorological Service was placed in the charge of a British meteorological officer in November, 1939, and has since been under the virtual control of the Air Ministry.

(d) The general meteorological organisation in each area includes the following:

(i) A senior meteorological officer who acts as meteorological adviser to the A.C.C. and co-ordinates requirements throughout the area under the Chief Meteorological Officer, Middle East;

(ii) A Central Forecasting Unit responsible for the collection and dissemination of meteorological information throughout the area and for the exchange of meteorological data with adjacent areas;

(iii) Subsidiary forecasting units, generally at Group H.Q., for the provision of local operational forecasts;

(iv) Meteorological interpreters and observers at operational stations, and at staging posts on reinforcing routes, for decoding and interpreting meteorological reports and forecasts;

(v) Mobile observing units for the provision of meteorological data to the artillery or for other special purposes.

52. The meteorological organisation in the Middle East may be summarised as follows:-

Egypt and Libya. Includes the Headquarters of the Meteorological Service and a Training School, a Central Forecasting Unit, with Meteorological Flights, several subsidiary forecasting units and interpreter and observing stations. A network of observing stations is also maintained by the Egyptian Civil Department.

Sudan. A Central Forecasting Unit, with Meteorological Flights, subsidiary forecasting units and interpreter stations.

British East Africa. A subsidiary forecasting unit with a network of observing stations manned by native personnel.

Aden. Headquarters and Central Forecasting Unit, with a Meteorological Flight, a subsidiary forecasting unit and several interpreter and observing stations some of which are manned by Indian personnel.

Italian Somaliland. A subsidiary forecasting unit with a network of observing stations manned by native personnel.

British East Africa. Headquarters and Central Forecasting Unit, with Meteorological Flights and a number of subsidiary forecasting units. A network of observing stations manned by native personnel.

Palestine and Transjordan. Headquarters and Central Forecasting Unit with a Meteorological Flight and subsidiary forecasting units and interpreter stations. A network of observing stations is maintained by the Palestine Meteorological Service manned by native personnel.

Syria. Headquarters and Central Forecasting Unit. A network of observing stations is controlled and manned by French personnel.

Cyprus. A subsidiary forecasting unit and a meteorological flight, observing stations manned by native personnel.

India and Persia. Headquarters and Central Forecasting Unit, with a Meteorological Flight, subsidiary forecasting units and interpreter and observing stations. A network of observing stations is maintained also in Iraq by the Iraqi Meteorological Service under the control of the Chief Meteorological Officer, Iraq. The observing stations in Persia are manned chiefly by native part-time personnel.

53. A number of additions to the above organisation have been approved. They consist mostly of interpreter and observing stations but additional subsidiary forecast units are included for Sudan and Italian Somaliland.

54. **South-east Asia.** - Responsibility for basic meteorological facilities in India rests with the Director General of Observatories, India. A Chief Meteorological Officer has been appointed to Headquarters, Air Command, South-East Asia, while forecast centres are being established at Group Headquarters and operational airfields, staffed with Meteorological Office personnel.

A special forecast centre staffed jointly with the Naval Meteorological Service is located in Ceylon and is responsible for meteorological forecasts for the Indian Ocean.

IV. METEOROLOGICAL ORGANISATION FOR THE ARMY

GENERAL

55. The Meteorological Office, Air Ministry, is responsible for meeting the meteorological requirements of the Army at home and overseas. M.O.S. is the Headquarters Branch generally responsible for administration of Army services.

56. The following types of Meteorological Sections of the R.A.F. Meteorological Branch are attached to Army formations and units in the field:-

Army Group H.Q.	Type I Section
Army H.Q.	1 officer and 4 assistants
Corps H.Q.	1 officer and 2 assistants
Divisional and Army Group } R.A.H.Q.	at each H.Q.
Sound Ranging Batteries	1 officer and 5 assistants
Observing Units	3 assistants
Smoke Companies	Special sections

RELATIONSHIP TO ARMY ORGANISATION

57. The Meteorological Sections which serve Army Group H.Q. and Army H.Q., (para. 56) are located with the associated R.A.F. H.Q., viz., the Tactical Air Force and R.A.F. Composite Group H.Q. The sections at and below Corps function as sections of the General Staff of the H.Q. to which they are attached.

FUNCTIONS OF THE SECTIONS AND UNITS

58. The functions of the various types of Meteorological Section or Unit are as follows:

(a) The section serving the H.Q. of an Army Group is responsible for meeting the requirements of the General Staff at the Army Group H.Q. and for co-ordinating the meteorological facilities and information provided by the sections at H.Q. of Armies and lower formations in the Groups. The section meets the requirements of those formations or units operationally controlled direct from the Army Group H.Q.

(b) Army H.Q. Sections meet the requirements of the Army H.Q. staff and those of the formations or units directly controlled by the Army H.Q. They also furnish the forecasts and guidance required by the smaller meteorological sections at the H.Q. of Corps and lower formations.

(c) The meteorological sections at H.Q. of Corps, Division R.A., and Army Group R.A., have as their primary function the provision of meteorological information for the artillery using the guidance received from the Army H.Q. These sections also meet the forecast requirements of their H.Q. staff. The meteorological officer in charge of each Corps Section co-ordinates the work of the various sections at lower formations in his Corps area and arranges for special requirements, not provided by those sections, to be met.

(4) Sound Ranging Sections, each capable of functioning as two separate units, are attached to S.R. Batteries for providing information on the wind and temperature structure.

(a) Observing Units, one to each Corps, are allocated to meet any special artillery requirements in the Corps area.

53. The sections at and below Corps H.Q. are equipped to make their own pilot balloon ascents and standard meteorological observations; they obtain their general guidance from the forecast sections at Army Group H.Q. or Army H.Q. The distribution of information provided by the various sections attached to Army formations is effected through Army communication channels.

50. Technical equipment for Army sections and units is supplied by the Meteorological Office, apart from certain special apparatus for chemical warfare purposes which is provided by the War Office. Transport and drivers for the sections at and below Corps level are provided by the Army.

7. METEOROLOGICAL ARRANGEMENTS FOR ANTI-AIRCRAFT CO-ORDINATION

51. The Headquarters Branch responsible for meeting the requirements of A.A. Command is M.O.8. The main requirements are meteorological reports every 4 hours, to all A.A. Gun Operations Rooms throughout Great Britain. The meteorological reports for the Operations Rooms in each area are prepared by the meteorological sections at the Headquarters of Groups in Fighter Command on the basis of forecasted upper winds and temperatures: the reports are distributed through A.A. Command channels.

VII. METEOROLOGICAL ARRANGEMENTS FOR THE MINISTRY OF SUPPLY

52. The Headquarters Branch responsible for providing meteorological information to the Ministry of Supply is M.O.8.

Meteorological Sections, comprising both Technical Officers and Assistants, are located at the experimental establishments of the Ministry of Supply for experimental work on artillery and chemical warfare problems.

VII. METEOROLOGICAL ARRANGEMENTS FOR THE MINISTRY OF FUEL AND POWER

53. M.O.14 is the Headquarters Branch responsible for supervising the meteorological advice and assistance provided to the Petroleum Warfare Department of the Ministry of Fuel and Power in investigations on fog dispersal. A section is maintained at the Headquarters of the Petroleum Warfare Department, with sub-sections at experimental establishments and airfields as required by the course of investigations.

VIII. METEOROLOGICAL OFFICE COMMUNICATIONS ORGANISATION

TELEPRINTER ORGANISATION

54. Meteorological observations and forecasts are distributed in Great Britain over the meteorological teleprinter network.

55. This network has its centre at the Central Forecasting Office. The lines and teleprinters are provided by the General Post Office acting on requests from the Director-General of Signals, Air Ministry, which works in close collaboration with the Meteorological Office.

56. From the Central Forecasting Office two direct teleprinter channels go to each Type 1 station. One of these, called "First Channel", runs to the Type 1 station and thence to the subsidiary meteorological offices of the Group. The other line, called "Second Channel", does not go beyond the Type 1 office. The first

Channel is used for general broadcasts to all meteorological stations in the teleprinter network. These stations can both receive and transmit, but at a few stations reception facilities only are provided. Besides the first time to Type 1 station from the Central Forecasting Office there are direct channels to certain Naval Meteorological Offices.

67. The following is a brief summary of arrangements for collecting and broadcasting on the First Channel:-

Between hour minus 5 minutes and the hour, each Type 1 station collects the observations made at each of its subsidiary stations "tails". Between the hour and hour-plus-10 minutes, the Type 1 station transmits all the reports to the Central Forecasting Office and to all its "tails" simultaneously. During those periods no broadcasting from the Central Forecasting Office takes place. From hour-plus-10 to hour-plus-15 minutes, the Central Forecasting Office broadcasts the British surface observations and priority Continental reports to all stations. During the rest of the hour there are broadcasts at fixed times, varying from hour to hour, of upper wind and temperature observations, foreign observations, aircraft observations, reports from ships, forecasts and analyses. In each hour there are brief periods called "breaks" during which there is no broadcasting and which are used for transmitting urgent administrative messages.

68. The Second Channel from the Central Forecasting Office to Type 1 stations is used partly for broadcasts of special information and partly for urgent administrative messages. If Type 1 stations wish to transmit to "tails" any of the information received on the Second Channel they have to retransmit it to them during the "breaks".

69. Meteorological observations made at non-meteorological office stations such as lighthouses, Royal Naval Shore Signal Stations (Coastguards) and posts of the Royal Observer Corps are telephoned to the nearest Type 1 station for transmission to the Central Forecasting Office.

70. Commands, Wings and Stations of the U.S.A.A.F. in the European Theatre of Operations are provided with similar teleprinter communications to the R.A.F., the U.S. and Meteorological Office Central Forecasting Offices being linked for this purpose.

WIRELESS ORGANISATION

71. Meteorological information is broadcast by W/T in either for the use of meteorological offices overseas, H.M. Navy and, as necessary, of meteorological offices at home.

72. There is also a point-to-point exchange for meteorological information and forecasts between those meteorological offices in the United Kingdom and overseas responsible for Transatlantic and other long distance flights.

IX. - SECURITY AND CYPHERS

POLICY

73. The security regulations and precautions described below apply to "meteorological security areas" i.e. areas for which it is necessary to deny meteorological information to the enemy. In such areas the general policy is:-

(i) Need for security is regarded as paramount.

(ii) Only in exceptional cases of emergency can the need for weather information take priority over security.

(iii) In other cases, if security cannot otherwise be achieved, weather information is suppressed.

74. In security areas meteorological information is classified as follows:-

(a) Current meteorological reports are normally "CONFIDENTIAL".

(11) Non-current meteorological reports are normally "CONFIDENTIAL".

Forecasts of a routine nature are "CONFIDENTIAL".

Special forecasts may be "CONFIDENTIAL", "SECRET" or "TOP SECRET". The classification is decided when the forecast, or series of forecasts, is arranged, and the forecasts are marked accordingly.

(12) Analyses and general inferences are normally "CONFIDENTIAL".

X. LIAISON ARRANGEMENTS

Admiralty. - Close liaison is maintained with the Directorate of the Royal Meteorological Service at the Admiralty.

The three meteorological offices of the Naval Service in Great Britain are in the meteorological teleprinter network and receive the forecasts and analyses prepared by the Central Forecasting Office and the broadcasts of observations of all kinds. They also make and transmit observations to the Central Forecasting Office.

United States of America. - A Senior Technical Officer is attached to the Royal Air Force Delegation, Washington, for liaison with the U.S. Weather Bureau, the U.S. Navy and Army Air Corps Weather Services and other authorities in the U.S.A. He represents the Meteorological Office on the Combined Meteorological Committee.

United States Army Air Force. - A liaison officer is attached to the Headquarters of the U.S.A.A.F. Weather Service in the European Theatre of Operations. Liaison officers are attached as required to the Weather Stations at U.S.A.A.F. Commands, Wings and Stations.

XI. TECHNICAL FACILITIES EMPLOYED BY THE METEOROLOGICAL OFFICE

The following sections describe the technical facilities brought into use by the Meteorological Office in the last few years.

METEOROLOGICAL FLIGHTS

Four classes of special aircraft flights are employed for obtaining meteorological information, viz:-

- (a) Medium altitude. Vertical ascents to 400 mb. (24,000 ft. approximately) 3 or 4 times daily.
- (b) High altitude. Vertical ascent to approximately 200 mb.; once daily.
- (c) High altitude reconnaissance flights as necessary.
- (d) Medium and long range reconnaissance over the sea, with vertical soundings between the surface and 500 mb. (18,000 feet approximately) once or more on each sortie; sorties generally twice daily.

The observations are sent in special code to the Central Forecasting Office which broadcasts them.

73. Additional information regarding these flights is given below:-

- (a) Medium Altitude Aircraft Ascents. - Observations of temperature and humidity are taken at an altimeter height of 500, 1000 and 1,500 feet, above the airfield and thereafter at 950, 900, 850 450, 400 mb. Observations of weather, clouds, visibility and ice formation are made in addition.
- (b) High Altitude Ascents. - Readings of dry bulb temperature are made at the following levels, 350, 700, 900, 950, 1000, 1050, 1100, 1150, 1200, 1250, 1300, 1350, 1400, 1450, 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950, 2000, 2050, 2100, 2150, 2200, 2250, 2300, 2350, 2400, 2450, 2500, 2550, 2600, 2650, 2700, 2750, 2800, 2850, 2900, 2950, 3000, 3050, 3100, 3150, 3200, 3250, 3300, 3350, 3400, 3450, 3500, 3550, 3600, 3650, 3700, 3750, 3800, 3850, 3900, 3950, 4000, 4050, 4100, 4150, 4200, 4250, 4300, 4350, 4400, 4450, 4500, 4550, 4600, 4650, 4700, 4750, 4800, 4850, 4900, 4950, 5000, 5050, 5100, 5150, 5200, 5250, 5300, 5350, 5400, 5450, 5500, 5550, 5600, 5650, 5700, 5750, 5800, 5850, 5900, 5950, 6000, 6050, 6100, 6150, 6200, 6250, 6300, 6350, 6400, 6450, 6500, 6550, 6600, 6650, 6700, 6750, 6800, 6850, 6900, 6950, 7000, 7050, 7100, 7150, 7200, 7250, 7300, 7350, 7400, 7450, 7500, 7550, 7600, 7650, 7700, 7750, 7800, 7850, 7900, 7950, 8000, 8050, 8100, 8150, 8200, 8250, 8300, 8350, 8400, 8450, 8500, 8550, 8600, 8650, 8700, 8750, 8800, 8850, 8900, 8950, 9000, 9050, 9100, 9150, 9200, 9250, 9300, 9350, 9400, 9450, 9500, 9550, 9600, 9650, 9700, 9750, 9800, 9850, 9900, 9950, 10000. Observations of weather, clouds, ice formation and condensation trails are made.

XII. TRAINING OF ROYAL AIR FORCE PERSONNEL IN METEOROLOGY

25. The general policy for the training of R.A.F. personnel in meteorology is that, so far as possible, the instruction shall be given by Meteorological Office staff.

It has not, however, been possible to arrange for Meteorological Office personnel to give all the meteorological instruction required in the Royal Air Force.

26. Meteorological instruction is given by meteorologists at the following units and courses:-

Empire Central Navigation School,
(Specialist Navigator course, Staff Navigator course).

School of General Reconnaissance,
(Navigation Reconnaissance Course).

Air Navigation and Bombing School,
(Theoretical training of Air Navigators).

Operational Training Units of Bomber, Fighter, Coastal and Transport Commands.

27. Other R.A.F. training units instruction is given, in general, by Navigation Officers who have undergone an advanced course of instruction in meteorology at the Empire Central Navigation School.

28. A meteorological officer is located at the Central Examinations Board of the R.A.F. to set meteorological examination papers. He is assisted in marking answer sheets by Education Officers of the Board.

XIII. OPERATIONAL STAFF OF THE METEOROLOGICAL OFFICE

29. This section defines the terms "Independent forecaster" etc., used in the description of the organisation of the synoptic side of the Meteorological Office.

The staff consist of

- (a) Independent forecasters;
- (b) Dependent forecasters;
- (c) Assistants.

29. Independent forecasters are qualified to originate forecasts from the synoptic charts and other material (upper air information etc.). They are guided as to the general lines of their forecasts by the analyses etc. issued by the Central Forecasting Office.

Independent forecasters normally hold a University degree in physics or mathematics. The pre-war grades for independent forecasters are Technical Officer and Assistant I. The war-time equivalents are Meteorologist I and Flight Lieutenant in the Meteorological Branch, R.A.F.V.R.

There are independent forecasters at Types 1 and 2 stations.

30. Dependent forecasters are stationed at Type 3 stations and receive forecasts from the Type 1 station. They receive the synoptic data and draw charts, which they use in explaining the forecasts and discussing them with aircrews.

The minimum technical qualification required in a dependent forecaster is the Intermediate 2-30, (or equivalent) with physics or mathematics. The pre-war grade for dependent forecaster is Assistant II; the war-time equivalents are Meteorologist II and Flying Officer (or Pilot Officer) in the Meteorological Branch, R.A.F.V.R.

31. The great majority of forecasters are men. A small number of women have been commissioned in the Meteorological Branch of the Women's Auxiliary Air Force (W.A.A.F.). Most of these W.A.A.F. officers are employed at non-operational stations.

32. Assistants make observations, attend to recording instruments, make the balloon ascents and plot weather maps. The majority of assistants in the United Kingdom are now aircrews of the W.A.A.F. and a few are employed at selected stations overseas. Most of the male assistants are employed in overseas units. The war-time grade for assistants is Assistant I. The war-time equivalents are Meteorological Assistant and Airman or Airwoman (Warrant Officer to W.A.A.F. or W.A.A.F. in the R.A.F. and W.A.A.F. respectively).

33. Independent and dependent forecasters, and assistants are also employed as meteorological air observers in Meteorological Reconnaissance Squadrons, and a special section (the Meteorological Air Observer Section) of the R.A.F. General Duties Branch has been formed for this purpose.

34. The following table shows the equivalent civilian grades and service ranks of meteorological personnel:-

Service Rank		Equivalent Civilian Grade	Typical Appointment
R.A.F.	W.A.A.F.		
Group Captain	Group Officer	I. OFFICERS Principal Technical Officer	Special.
Wing Commander	Wing Officer	Senior Technical Officer (I)	Officer-in-charge of small meteorological service.
Squadron Leader	Squadron Officer	Senior Technical Officer or Senior Meteorologist	Officer-in-charge of major forecasting station.
Flight Lieutenant	Flight Officer	Technical Officer or Assistant I	Independent forecaster.
Flying Officer Pilot Officer	Section Officer Assistant Section Officer	Assistant II	Dependent forecaster.
Warrant Officer	Warrant Officer	II. AIRMEN AND AIRWOMEN Assistant III(1)	Applicable only to senior subordinate in major overseas commands.
Flight Sergeant	Flight Sergeant	Assistant III(2)	Senior subordinate at the more important Type 1 stations not exceeding 20 in number at any one time.
Sergeant	Sergeant	Assistant III(3)	Senior subordinates at Type 1 stations where no Flight Sergeant post is available. Senior subordinate at Type 2 stations.
Corporal	Corporal	Assistant III(4)	Senior subordinate at Types 2 and 3 stations.
Leading Aircraftman	Leading Aircraftwoman	Assistant III	Junior subordinate at Type 1 stations, to the number of three and at Type 2 stations to the number of three. Basic Grade.

* Includes Meteorologist I.

† Includes Meteorologist II.

‡ The term Assistant III includes Meteorological Assistants.

§ Aircraftman, 2nd class, on entry.

¶ Aircraftwoman, 2nd class, on entry.

XIV. PUBLICATIONS OF THE METEOROLOGICAL OFFICE

75. At the outbreak of war it was decided, in the interests of economy, to suspend the issue of Meteorological Office publications which did not have a direct bearing upon the war effort. The following peace-time serial publications were suspended:-

Annual Report of the Director
British Rainfall
Marine Observer
Weekly Weather Report
Meteorological Magazine

Observatories' Year Book
Seismological Bulletin
Revue Mondiale
Geophysical Memoirs
Professional Notes

76. The following serial publications have been continued, but for security reasons they have been withdrawn from sale, and their distribution curtailed:-

Daily Weather Report
Monthly Weather Report
Monthly Frequency Tables

77. Publication has continued, for official use only, of certain papers and reports which have a direct bearing upon operational requirements of the Service Departments. A selection of these publications is listed below, new editions being marked with an asterisk:-

- * Handbook of Meteorology for Pilots and Navigators (M.O.448).
- * Cloud Atlas for Aviators (M.O.450).
- Weather in Home Waters (M.O.446).
- Weather in the Indian Ocean (M.O.451).
- Meteorological Office Radio Souds. Measurement of Temperature and Humidity (Radio-Thum) (M.O.462).
- Meteorological Office Radio Souds. Measurement of Upper Wind (Radio-Wind) (M.O.464).
- Measurement of upper winds by Radar Methods (M.O.M.468).
- Ice Atlases of Western North Atlantic and Arctic Seas (M.O.M.469 and 390A).
- Notes on the weather of the Far East Theatre (M.O.M.469).
- Rainfall maps of the Far East (M.O.M.471).

78. In order to meet the wartime requirements of the operational side of the Meteorological Office, a series of instructions relating to procedure, methods of reporting, and coding of meteorological reports have been instituted and are issued to all concerned. In addition, memoranda upon various scientific problems connected with synoptic meteorology are prepared from time to time and issued for the guidance of the forecasting staff. These instructions and memoranda are known as "Synoptic Divisions Instructions" and "Technical Memoranda".

XV. METEOROLOGICAL RESEARCH COMMITTEE

79. The Meteorological Research Committee has been set up with the following terms of reference:-

- (a) To advise the Secretary of State for Air as to the general lines along which meteorological research should be developed.
- (b) To advise and assist in the carrying out of investigations and research within the Meteorological Office.
- (c) To receive reports upon meteorological investigations carried out in the Meteorological Office or on behalf of the Air Ministry and to make recommendations for further action.

80. To co-ordinate the investigations performed in the Meteorological Office with related activities carried out elsewhere, both in other Government departments and in the private sector.

(e) To make an annual report to the Secretary of State for Air.

100. The composition of the Meteorological Research Committee is as follows:-

Chairman:- Professor S. Chapman, M.A., D.Sc., F.R.S.
Vice-Chairman:- Mr. G. M. D. Dobson, M.A., D.Sc., F.R.S.
Members:- Professor L. Brunt, M.A., D.Sc., F.R.S.
Professor Sir Geoffrey Taylor, M.A., D.Sc., F.R.S.
Director of the Meteorological Office.
Director of the Naval Meteorological Service.
Director of Scientific Research, Ministry of Aircraft Production.
Representative of the Air Staff.
Representative of the Director-General of Civil Aviation.

101. The Committee meets regularly. The research programme is revised annually and work upon a number of problems is in progress. Reports laid before the Committee which are considered to be of interest to other Meteorological Services are distributed from time to time; up to September 1944 the number so distributed was 59.

102. As a matter of general policy the Committee have decided to concentrate their attention for the time being upon practical and applied problems and have invited the co-operation of the Royal Society for dealing with investigations of a more purely scientific character. The Royal Society have expressed their willingness to assist in this way, and arrangements have been made for a comprehensive investigation into the various aspects of the problem of radiative equilibrium in the atmosphere.

N. E. JOHNSON,
Director.

Meteorological Office,
Air Ministry, London, W.C.2.

JANUARY, 1945.

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*See note inside
over the classification
of this publication.*

REPORT
OF THE METEOROLOGICAL IMPLICATIONS
IN THE SELECTION OF THE DAY FOR
THE ALLIED INVASION OF FRANCE
- JUNE 1944.

November, 1944.

The Director,
Meteorological Office,
Air Ministry.

Meteorological Report on Forecasting
Arrangements for the Allied Invasion
of France, June 1944.

In conformance with instructions from
the Chief of the Operations Section, Supreme
Headquarters, I am forwarding herewith for
your retention ten copies of a Report on the
Meteorological Implications in the Selection
of the day for the Allied Invasion of France,
June 1944.

(Signed) J.M. STAGG.

Group Captain.

Distribution:

D.M.O. (1).
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A.D.M.O. (O) (1).
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NOTE

During telephone discussion with Mr Karabouloukis, Mod Sy MB80957, 11 Jan 94, it was agreed that this document could be down-graded by any officer in DSHQ at HEO or equivalent. Document therefore down-graded to UNCLAS.



K Horner
DS Div Sy O
Room 122
Met O HQ
London Rd
BRACKNELL

11 Jan 94

REPORT

ON THE METEOROLOGICAL IMPLICATIONS
IN THE SELECTION OF THE DAY FOR
THE ALLIED INVASION OF FRANCE

JUNE 1944.

Report on the Meteorological Implications
In the selection of the day for the Allied Invasion of France,
June, 1944

FOREWORD

1. The Report embodied in the following pages is an attempt to summarise some of the more important aspects of the manner in which meteorology, more particularly weather forecasting, was involved in the decisions which led up to the invasion of France on 6th June 1944 by the combined naval, air and army Forces of Great Britain and the United States. The operation was known by the codeword NEPTUNE and is referred to by this word in the Report.

2. While aiming at completeness the Report is intended to bring out only those aspects which are necessary adequate appreciation of the problems confronting the meteorological advisors of the Supreme Commander. In that the Report has been prepared in the Meteorological Section, Supreme Headquarters, without reference to the various meteorological Services which contributed so valuably to the forecasts used in the decisions, the views expressed are solely those of the SHAEF Meteorological Section.

3. Every effort has been made to do adequate justice to the contributions of each of the Forecasting Centrals, made during the course of the long and difficult series of conferences conducted by telephone by day and by night. Whatever procedure may be adopted for any similar operation in the future, it is unlikely that a greater degree of enthusiastic and helpful co-operation on the part of all the participants will be achieved.

4. A Report of this nature made primarily to be a record of the part played by organised meteorology in an important invasion operation, would normally end with a review of the military decisions as affected by weather forecasts. It has, however, been considered that any value the Report may have, might be enhanced by summarising the experience of the Supreme Commander's meteorological advisors in a Section of "Comments and Recommendations". Such a Section has, therefore, been included.

5. All the purely technical discussions have been relegated to Appendices not because they are less important than any of the other sections, but because the Report is primarily a Report to the Supreme Commander and his Staff. The material in the Appendices is intended to provide information about the purely meteorological background for those readers who may wish to evaluate the contents of Section VI against the synoptic situation and developments during the most critical period.



Meteorological Section,
Supreme Headquarters Allied Expeditionary Force,
22nd June, 1944

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Report on the Meteorological Implications in the Selection of the day for
the Allied Invasion of France, June 1944.

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Report on the Meteorological implications in the selection
of the day for the Allied Invasion of France, 1944.

I. Meteorological Requirements for the Various Phases of the Assault.

a. General Considerations

For such a complex operation as a landing on a heavily fortified coast, it is not an easy matter to determine one set of meteorological conditions which would be ideal from the points of view of all the arms concerned. The ideal conditions would change with the stage of the operation; in the hours immediately preceding and following the actual hour of first landing, the conditions would vary almost from hour to hour. Cloud conditions that would be most suitable for the landing of Airborne forces at HH-X hours would not necessarily be those that would give the heavy bombers their best opportunities at HH-Y hours; and those conditions in turn might not be necessary or even most advantageous for medium and light bombers at HH-Z hours; fighters might operate successfully under conditions different from those considered ideal for the troop carriers or for the heavy or medium bombers.

Probably the only firm prerequisite is the restriction on the strength (and in part on the direction) of the surface wind with its immediate effect on the state of the sea both for the crossing before the landings and its effect on the waves and surf on the landing beaches. But the wind at the time of crossing and at the time of landings is not the only factor affecting this aspect of the operation. If the sea and the beaches are open to the direction from which swell produced by high winds up to hundreds of miles away, is liable to come, then the force and direction of winds hundreds of miles away from the operational area have to be taken into account. And the local conditions of sea are affected by the strength, direction and duration of the local winds for a number of hours before the critical time, depending on the fetch of the particular coast.

Hence, from the viewpoint of naval operations alone, the ideal conditions would be little or no wind within the actual sphere of operations and no swell-producing wind for the whole period covering the time of sailing of the assault forces to their landings on the beaches.

Visibility, as affected vertically by cloud and horizontally on the surface by fog, mist/haze, is one of the most important factors for the Air and Naval aspects of the operation. Visibility must be good enough to let the various types of aircraft take off from, and assemble over, their bases and see their targets in and behind the assault area; visibility must be adequate at sea to allow the multitude of craft involved keep their proper station and also allow the naval bombarding forces see their targets on land in close bombardment; the aircraft spotting for the naval bombarding force must also have visibility adequate for directing the force on to its land or sea targets.

There are other factors; for example, the condition of the ground in the operational area as regards softness (mudiness) for the movement of heavy vehicles both tracked and untracked. This factor is taken account of in the planning stages but in certain circumstances may also be important in deciding the day of assault.

Of a more detailed character, but in certain contingencies by no means unimportant, are the actual conditions as regards vertical temperature structure in the atmosphere and wind speed and direction along the coast line immediately preceding, at, and following HH hour. These conditions determine the behavior of smoke screens.

b. Actual Limiting Conditions Used for the NEPTUNE Operation

In English weather, even English summer weather, it was clearly impracticable to set up an ideal set of conditions even if such were possible and defer the assault until this set of conditions was obtained. In the summers of some years they would never be obtained within any predetermined period of, say, a month or even two months. Besides, other factors quite apart from the purely military and political factors, are (unfortunately) at least as important in

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determining the period within which the assault must be affected. These factors include the times of high and low tides and the intensity of ground illumination as affected by twilight and phase and altitude of the moon.

It was therefore necessary to define a set of minimum meteorological conditions which could be accepted by all arms as being the worst conditions in which the operation could be launched.

Such a set of minimum conditions were never wholly accepted by all the forces but the following represents the conditions which the Meteorological Section SHAEF kept in mind:

NAVAL Requirements.

- (1) Surface winds should not exceed Force 3 (8-12 mph) on shore or Force 4 (13-18 mph) off shore in the assault area during the days D to D plus 2. Winds might be Force 5 in the open sea but only for limited periods.
- (2) In the days preceding D-Day, there should be no prolonged periods of high winds of such direction and in such Atlantic areas as to produce any substantial swell in the Channel.
- (3) Visibility, not less than 3 miles.

AIR FORCE Requirements.

- (1) Airborne transport; (HH-6 to HH-4):
 - (a) Cloud ceiling at least 2500 feet along the route to and over the target area.
 - (b) Visibility at least 3 miles.
- (2) Heavy Bombers (HH-4 to HH):
 - (a) Not more than 5/10 cloud cover below 5000 feet and cloud ceiling not lower than 11000 feet over the target area.
- (3) Medium and Fighter Bombers (HH-2 onwards):
 - (a) Cloud ceiling not less than 4500 feet, visibility not less than 3 miles over the target area.
- (4) Fighter and Fighter Bombers (HH-16 onwards):
 - (a) Cloud base not less than 1000 feet.
- (5) Base areas:
 - (a) Cloud not below 1000 feet and visibility not below a mile except for heavy bombers for which there is the additional stipulation that low cloud tops must be less than 5000 feet high and there should be only fragmentary middle cloud.

ARMY Requirements.

- (1) Airborne Troops Landings:
 - (a) For Paratroops, the surface wind over the target area should not exceed 20 mph in the target area and should not be gusty; and for gliders the surface wind should not be over 30-35 mph.
 - (b) The intensity of the ground illumination should not be less than half moon at 30° altitude or the equivalent in diffuse twilight.

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(2) Ground Forces:

The ground should be sufficiently dry to allow movement of heavy vehicles off made-up roads.

II. Summary of Results of Statistical Examination of the Probability of Obtaining Most of the Above Requirements on Any One Day or Sequence of Days.

In the months preceding the launching of operation NEPTUNE, examinations of weather statistics for past years were made from many different angles with a view to estimating the probability of obtaining specified weather conditions at various periods from April onwards. Some of the results obtained at various times, using different sets of basic information, were as follows:-

Defining a quiet day as one with wind less than Force 3 onshore and Force 4 offshore, on the Normandy Coast of France and stipulating the following overall requirements for the periods of the assault;

- (a) D-Day be within the period of one day before to four days after new or full moon (that is assuming landing of Airborne troops could be affected irrespective of ground illumination from moon light)
- (b) D-Day be itself quiet and followed by a sequence of three quiet days.
- (c) Cloud less than 3/10 below 8000 feet and visibility more than 3 miles.
- (d) Alternative to (c), cloud base generally above 3000 feet and with morning mist or fog not excluded.

The following arithmetical values were obtained for the probabilities of the various conditions (a), (b), (c) and (d) above:

	May	June	July
	<u>Chances to 1 Against</u>		
(1) (a) (b) and (c) together	24	13	50
(b) and (c) without (a)	9	4½	19
(b) and (c) with (a) limited to full moon	49	24	100
(2) (a) (b) and (d) together	11	6	16
(b) and (d), without (a)	4	2	5
(b) and (d) with (a) limited to full moon	24	13	33

Of these various sets of conditions, the third set in the second group was the most likely to have to be accepted, viz. D to D plus 3 quiet as regards wind, cloud base generally above 3000 feet and the conditions restricted in any one month to six days around full moon. Even with those conditions which did not cover the minimum requirements for some of the phases of the operations, the chances of obtaining the conditions together over a set of days were very low, viz. 24 to 1 against in May, 13 to 1 against in June and 33 to 1 in July. One important result did come out from these and many other examinations, viz. that June was likely to be the best of the three early summer months. So that if the operation was planned for May and postponed, June, with better chances, was still to come; but if the operation were planned for June and deferred, its chances of similar conditions in July (and subsequent months) would be less good than for May or June.

There were, of course, meteorological reasons for avoiding May for Channel operations if at all practicable; one of these was the statistical frequency of occurrence of winds from between northeast and east in the eastern and central Channel area. These winds coming over the water of the cool North Sea bring low stratus cloud liable to persist with 10/10 cover for days at a time in the central and eastern Channel area.

III. The procedure for achieving an agreed weather forecast for the NEPTUNE Operation.

As statistics from past years' weather were known to be quite an unreliable and unhelpful guide for the actual selection of D-Day, it was decided at a meeting of the Directors of the Meteorological Services concerned (Air Ministry, U.S. and Naval) in January 1944, that the utmost efforts should be directed to framing as a routine procedure each week, a forecast of weather conditions covering as long a period ahead as could be issued with substantial confidence; 5 days was the period aimed at.

It was arranged that regular conferences be held using scrambler telephone conference facilities and with the following participants:

Air Ministry Forecasting Central, Dunstable
U. S. Forecasting Central, Washington
Naval Meteorological Forecasting Central, Admiralty

The Chief Meteorological Officer at SHAEF or his Deputy was to be the Chairman at each of the conferences which would include the Meteorological Staff Officer of the Naval Commander in Chief, and the Chief Meteorological Officer (or his Deputy) at the Headquarters, Allied Expeditionary Air Force.

The purpose of the conferences was to arrive at an agreed forecast for a period of 5 days; the advice to be submitted to the Supreme Commander and his Commanders-in-Chief would be based on this agreed forecast.

These conferences started in February 1944, at first on a two or three times a week basis; from the middle of April, the conferences were held each day.

Actually the need for daily conferences became necessary for at least two different reasons;

- (1) In all but abnormally (for England) quiet conditions, the expert and experienced meteorologists at the participating Centrals seldom found it practicable to forecast with any useful confidence beyond 2 or 3 days; and
- (2) The original intention of restricting the functions of the conferences to the framing of an agreed planning forecast developed into aiming at giving broad operational details for at least the first two or three days. Events soon showed that daily modification of the forecast was necessary to ensure that those details be operationally useful to the senior meteorological officers at the lower formations to which the agreed forecasts were distributed.

For large scale exercises and operations preceding the actual NEPTUNE assault (e.g. the FAEIUS operation on 3rd May 1944), and more particularly as the scheduled day of the NEPTUNE operation approached, the number of conferences between the forecasting Centrals and the Meteorological Advisors to the Naval and Air C's-in-C was increased to three a day;

- (1) A preliminary conference in the late afternoon (1730 h) to allow the Centrals to discuss the lines on which they were thinking about synoptic developments over the next five days.
- (2) A main conference in the late evening (2100 h) at which the terms of a 5-day forecast (agreed or accepted by all concerned) were discussed. And
- (3) A morning conference (varying in time from 0630 to 0830 h) at which any necessary modifications in the operational part of the previous evening's 5-day forecast were discussed and a modified forecast issued if required.

On the days immediately preceding D-Day, a further conference was held at 0300 each morning on which to base the final advice given to the Supreme Commander's meetings at 0415.

Each of the conferences usually lasted about one hour; they sometimes extended to two hours, particularly the evening conferences preceding D-Day.

IV. Forecasts of Weather suitable for Assault Operations, submitted during May, 1944, to Supreme Commander or his Staff:

With a view to testing the effectiveness of the information contained in the five-day forecasts prepared by the procedure outlined in the preceding section, the Meteorological Section, SHAEF, was instructed to submit each day those dates at least two days ahead when it was thought that conditions would fulfil most of the requirements referred to in Section I. In effect, each day more than two days ahead was to be considered as a possible D-Day, and the conditions on that day and on immediately preceding and succeeding days were to be considered in the light of their suitability for launching an assault. If the conditions were considered as likely to be suitable, the Assistant Chief of Staff, Plans and Operations (G-3) Division was informed.

From the early days of May, a total of eighteen dates (including the first two days of June) were submitted either separately or in sequences of two or more days, as days for which the weather was forecast at least two days in advance as being suitable for launching an attack on the selected coast of France.

Considering that the weather in May was mainly of a settled type, it was not surprising that the weather on these dates did in fact turn out to be substantially as forecast and suitable for launching a large scale assault.

V. Weather information and advice furnished to the Supreme Commander's Staff in the preparatory stages of Operation NEPTUNE viz. on May 28th, 29th, 31st and June 1st.)

- (1) In this period during which decisions had to be taken for the sailing of those assault and naval bombardment forces which were coming from a considerable distance, it was recognized that no definite forecast could be given for conditions on and immediately following the scheduled D-Day, 5th June.
- (2) On Sunday, 28th May, the Supreme Commander was advised through the Assistant Chief of Staff, G-3 Division, SHAEF, that the evidence then was that mainly quiet wind conditions would continue during the week. Even in the present stable situation, nothing helpful could be said about wind or cloud conditions on D-Day but the risk of conditions changing so much from what they are now as to produce a gale in the Channel then seemed rather small.
- (3) On Monday, 29th May, to a meeting at 1000 hours at Portsmouth, of the Supreme Commander, his Commanders-in-Chief, and their Chiefs of Staff, the following forecast was presented for the five days until Friday, 2nd June.

Mainly quiet wind conditions (not more than Force 4) throughout the period except for a wind of Force 5 in the extreme western Channel areas on Thursday and Friday.

Variable cloud conditions with an average of 5/10 to 7/10 except in local thunderstorms during the first two or three days; cloud would probably increase from the west at the end of the period. The visibility would be good except for morning coastal haze and in thundery showers.

The confidence was given as moderate for continuation of quiet wind conditions but low for details of cloudiness and developments toward Thursday and Friday.

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In course of questioning at this meeting about conditions for Saturday, 3rd June, it was repeated that there was a risk of deterioration at that time especially as regards cloud conditions, but that the outlook was favorable from the viewpoint of wind in the Channel.

The basis of this advice was that there was no evidence to indicate that the existing northeasterly extension of the Azores high pressure area would be substantially modified in the next four or five days; it was therefore a reasonable expectation that, even if it did begin to recede or collapse at the end of that time, it would still influence the movements and intensities of any low pressure systems that might effect the operational area by giving them a northeasterly track away from the English Channel.

- (4) 0830, Wednesday, 31 May. The Assistant Chief of Staff, G-3, SHAIR, was advised that since Monday morning's conference at Portsmouth, the situation did not look as favorable as it then did for weather in the Channel area from Sunday, 4th June, onwards. But there was as yet no definite evidence that winds would be substantially above Force 4 for long periods; nothing helpful could be said at that stage about cloud conditions on June 4th and 5th.

This advice was based on the prognostic analyses agreed by the forecasting centrals to the effect that there were indications that the Azores high pressure area was beginning to show signs of weakening, though there was time for a replacement high pressure area to move in or resuscitate it from the west.

- (5) 0845, Thursday, 1st June. The AC of S, G-3, (General Bull) was advised that there was no new evidence to change the forecast as given him yesterday (para.(4)). The balance of evidence was that wind in the Channel area should continue not more than Force 4 over the weekend and on Monday, 5th June, but no forecast for cloud could be given. The confidence in operationally quiet wind conditions continuing into Monday was somewhat less than in the forecast given on Wednesday.

VI. Summary of Meteorological statements made at the Supreme Commander's meetings at Portsmouth (Friday 2nd June to Monday 5th June).

In their essentials, the statements are reproduced in as nearly as practicable the same form of words as were used at the meetings.

1000 Friday, 2nd June.

Winds in the Channel and particularly in the Normandy area will probably be westerly, mainly not above Force 4, but Force 5 at times particularly in the western channel towards the end of the period (Monday and Tuesday).

Cloud conditions on Sunday and Monday cannot be forecast with any degree of confidence; they will be variable. Amounts will be 7/10 to 10/10 in the early morning in the operational area, clearing partially in the forenoon to 5/10 or less but with patches up to 10/10 for considerable periods.

Visibility will be moderate to good generally but with risk of fog patches in the Channel and coastal areas on Monday morning.

The general type of weather is westerly in which Force 5 winds cannot be ignored at any time and in the warm humid air brought across the Atlantic from lower latitudes, cloud conditions are always uncertain particularly over higher ground in coastal areas and in the southwest of the Channel area.

There is now indication that the present relatively quiet weather may end about Tuesday.

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2130 Friday 2nd June.

The general meteorological situation has not changed substantially and the forecast presented at the morning conference still stands. The flow of moist warm air over the operational areas will produce much low cloud. The whole development is at the moment sluggish and slow to show its hand; but, on the whole, the outlook for Sunday and Monday seems not unfavorable from the point of view of wind speed, namely, mainly Force 4; but there is a risk of Force 5 winds on Tuesday. The outlook for cloudiness is very uncertain; considerable periods of 10/10 cloud cover with base about 1000 feet must be expected. The times of such periods cannot be forecast accurately.

To a question (Supreme Commander) about conditions on Tuesday and Wednesday the reply was that the evidence at present did not indicate much difference on those days from the conditions as just described for Sunday or Monday; there was no basis for forecasting persistent high winds though there was a risk of Force 5 on Tuesday; cloud conditions would probably continue poor with periods of 10/10 at 1000 feet.

Another inquiry (D/Air C-in-C: Gen. Vandenburg) was directed to conditions for the transport and landing of Airborne troops overnight Sunday-Monday. The reply was that cloud base would probably be mainly above 1000 feet but there would be patches with base at or below 1000 feet after 0200 on Monday morning.

0800, Saturday, 3rd June.

AC of S, G-3 (Gen. Bull) was informed by telephone that there was no indication of improvement from the terms of the forecast presented at 2130 the previous evening. But the risk of Force 5 winds then forecast for Tuesday had now to be brought into Monday and even the latter part of Sunday. The view at the moment was that these Force 5's would be mainly on the English Channel coast.

The cloud forecast is still very uncertain; the most likely cloud conditions are 7/10 to 10/10, base 1000 feet, especially in the early morning hours. No opinion can be expressed about exact times of clearances, except for areas well inland during the afternoon.

General Vandenburg (D/Air C-in-C) and Admiral Creasy (C of S to Naval C-in-C) were given the same information. It was emphasized that the synoptic situation had become an extremely difficult one, and forecasts as to details were given with low confidence.

2130, Saturday, 3rd June. Supreme Commander's Meeting.

The high pressure area over the Azores is rapidly giving way and a series of depressions across the Atlantic is moving rapidly eastward; these depressions will produce disturbed conditions in the Channel and assault area.

Winds will be west-southwest, Force 5 on English Coast, Force 3-4 on the French Coasts from early Sunday, until a cold front trough passes. That passage is timed to be sometime on Wednesday, 7th June.

From Sunday morning onwards, cloud will probably be mainly 10/10 with base 500-1000 feet in the morning hours. This cloud may break in inland areas during the day and become about 5/10, but will continue of variable amounts in the Channel area and on both coasts with considerable patches of 10/10; its base will be at or below 1000 feet. The time of incidence and local distribution of these patches of low cloud cannot be forecast with confidence.

Some patches of medium and high cloud, mainly confined to South England must also be expected; amounts of this type of cloud will be less in areas well inland, e.g. over the Eastern Midlands and over the East Anglia bomber base areas.

Visibility will be mainly 3-4 miles, though 5-6 miles inland in the afternoon can be expected. There is a risk of fog spreading from the West up the Channel to sea and coastal areas. After Monday this risk of fog will decrease.

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These details cover the period Sunday to Tuesday and at first on Wednesday, as far as can be seen with any confidence at the moment.

During Wednesday, a front associated with a depression now off Nova Scotia and the New England States will probably pass through the assault area.

Just preceding this front there will be a period of 10/10 multilayer cloud (low, medium and high); then as the front passes there will be a decrease of cloud amount and increase of cloud base heights, becoming 5/10 to 2500 feet. Visibility on Wednesday will be moderate at first becoming good after the front passes.

Further meteorological forecasts and statements made at this meeting were as follows:

- (a) Air C-in-C, on a question about likely conditions for heavy bombers taking off from bases early on Monday morning:

10/10 stratus cloud, base 500-1000 feet and about 3000 feet thick; with a second layer of medium cloud base between 8000 feet and 12000 feet. This second upper layer will probably not be a continuous 10/10ths sheet.

- (b) Air C-in-C, about conditions for enemy aircraft using their own bases:

Cloud along the French Coasts will probably be 10/10, base 500-1000 feet; but inland, away from the coastal strip, cloud amounts may be expected to be less during the middle part of the day.

Conditions over enemy bases on Monday will, on the whole, be better than over bases in England.

- (c) Naval C-in-C, whether Force 5 winds along the English Channel are likely to continue through Monday and on Tuesday. Force 5 winds must be expected on Monday and on Tuesday.

- (d) Naval C-in-C; would cloud conditions also be similar on Tuesday?

Similar cloud conditions will probably continue from about Sunday forenoon until Wednesday, when the clearing front is due to pass through the operational areas.
No useful forecast can be given beyond that at present.

- (e) To a general question about probable weather conditions after Wednesday, the reply was that weather could not be expected to settle down quickly after the present very disturbed situation. But the prospects were, alternation of periods of greater and less cloudiness with mainly moderate westerly wind though fresh at times, associated with minor fronts and ridges of high pressure.

- (f) The Supreme Commander commented on the slightly more optimistic note that he felt had come into the picture between the morning and evening conferences on Friday; and asked whether the forecast might not be more optimistic again tomorrow morning.

There is very little chance of any information being received before 0300 which is likely to give a more optimistic turn to the forecast. Since at least yesterday (Friday) morning, the whole meteorological situation has looked very unpropitious for a Monday assault but the outlook has been finely balanced in that it might have swung to better or much worse. On Friday evening there was a very slight tip of the balance on the favorable side but the balance now has swung too far to the unfavorable side for it to be quickly counteracted.

The supreme Commander said that he had certainly been left on Friday morning with the impression that the situation was both difficult and uncertain.

- (g) Deputy Supreme Commander asked whether the meteorological centrals were all agreed about the forecast as presented.

The centrals have agreed to accept the forecast.

(Following the presentation of this information, the assault was provisionally postponed for 24 hours.)

0415, Sunday, 4th June.

No new evidence has been received which allows any substantial change in the forecast presented last (Saturday) evening. The only small change is that the front, which was then expected to clear the Channel areas of low cloud on Wednesday, is now expected in the first part of Wednesday.

Winds will be Force 5 in the Channel from early Monday onwards, though somewhat less in sheltered areas on the French Coast.

10/10ths cloud, base 500-1000 feet are expected along the Channel area, with no forecastable difference in these conditions from Sunday to Tuesday.

The Naval C-in-C asked when these overcast skies would appear at Portsmouth, commenting that it was a practically clear sky with calm wind at the time of the meeting. He was advised that the cloud would increase during the early forenoon, of that day (Sunday).

(Following this presentation the time of the assault was deferred by 24 hours in the first instance.)

1745, Sunday, 4th June.

AC of S, G-3 was informed that there had been a substantial change in the situation since the early morning. It is now likely that there will be a fair interval starting about midnight today and lasting till about dawn on Tuesday morning. During this fair interval, and particularly from Monday evening to Tuesday morning, cloud amounts will probably be substantially smaller than given in forecast this morning; winds will also moderate temporarily, particularly over Monday night and at first on Tuesday.

A deterioration will probably set in again during Tuesday; weather on subsequent days will continue unsettled and disturbed.

On General Bull's request this same information was conveyed to General de Guingand (Chief of Staff to Army C-in-C).

2100, Sunday, 4th June. Supreme Commander's meeting.

Since the statement made before the meeting on Saturday evening, there have been some rapid and unexpected developments in the weather situation over the Atlantic. A front from one of the deep depressions in the northwest Atlantic has moved much farther south than was expected and is now traversing the Channel areas. It is almost over Portsmouth now and will clear the eastern Channel at least on the English side overnight. When that front has passed there will be an interval of fair conditions which, from the evidence we now have, should last until at least dawn on Tuesday.

Wind speeds by Monday evening should decrease to Force 3-4 on the French Channel coasts and cloud will become mainly less than 5/10, with base 2-3000 ft.

After that interval, lasting till Tuesday morning, cloud will probably increase to 8/10-10/10 from the west during Tuesday afternoon and will continue so overnight Tuesday.

From a time on Wednesday which cannot be defined from present information, mainly cloudy conditions will continue; but there should be some intervals of broken cloud. In this period from Wednesday to Friday, there will probably be intervals of 10/10ths cloud with base at 1000 feet; these overcast intervals of low cloud may be expected to last 4-6 hours at a time.

Wind will be mainly Force 4 on the English Channel coasts and Force 3-4 on French Channel coasts; in sheltered stretches of the French Channel coast periods of Force 2-3 could be expected. The wind direction throughout will be Westerly.

Additional meteorological statements were made at this meeting in reply to specific questions as follows:

Admiral Cressy (C of S to Naval C-in-C) asked if there was a chance that conditions from Wednesday to Friday might be better than those described in the main statement. He was advised that there was a reasonable chance that the weather systems which were expected to cause the temporary deteriorations after Tuesday would follow a more northeasterly track to Iceland or Southeast Greenland and if that happened the cloud conditions would probably be better than these now forecast. But nothing definite could be said at present about such future developments.

General Eisenhower asked if anything could be said about conditions beyond Friday. He was advised that the forecast even up to then could not be given with any substantial confidence. The general weather conditions must continue to be regarded as disturbed and unsettled; after the very vigorous shake-up in the whole synoptic situation over the North Atlantic which we are going through now, conditions cannot settle down immediately.

But considering the time of year and the evidence we now have, there is a reasonable prospect of weather slowly improving after Friday if the present trend of development over the period Wednesday to Friday comes out as now expected.

A.C.M. Tedder asked about the confidence in the forecast. In reply it was explained that pressure systems had formed, deepened and crossed the Atlantic at a rate appropriate to mid-winter. Confidence in the forecast for more than a short period ahead cannot be high; but there is a fair chance that the low pressure system now in the Newfoundland area will move on a northeasterly track and more slowly than its predecessors; if developments go that way, that should give the Azores high pressure system a chance to build up again and at least partially to protect the Channel areas from future depressions traversing the Atlantic from the west.

To A.C.M. Leigh-Mallory and General de Guingand who asked about the detailed cloud conditions expected overnight Monday-Tuesday, the information given was that following the clearance on Monday, cloud over the assault areas and the immediate hinterland would probably remain well broken from midnight Monday to Tuesday morning. The base of this cloud would probably be about 2500-3000 feet and could be expected to be not more than 5/10ths at any time in that area.

Asked by A.C.M. Leigh-Mallory if his meteorological advisors at Hq. AEF agreed with views presented at this meeting, the reply was that they did; their view was that good though not uninterrupted conditions for visual bombing by heavy and medium bombers could be expected from Monday evening till early forenoon Tuesday; then periods of good bombing alternating with poorer periods after the deterioration on Tuesday-Wednesday had passed.

Naval C-in-C, commenting on conditions for operation of spotting aircraft for naval bombardment, which required cloud base heights not below 2500 feet, was assured that conditions would probably be favorable for these spotting and reconnaissance operations.

(Following this meeting, provisional instructions were issued for launching the assault at 0630 on Tuesday morning.)

0415, Monday, 5th June.

There has been no substantial change in the information available since, or in the forecast presented at, the meeting yesterday (Sunday) evening.

The fair to fine interval which by 0415 had begun at Portsmouth will probably last into the forenoon of Tuesday. During this interval, cloud will be mainly less than 5/10ths, with base at 2500-3000 feet.

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Wind on the beaches in the assault area will probably not exceed Force 3 in this interval and will be westerly. Visibility will be good.

During Tuesday, cloud will very probably increase again from the west giving a period of overcast sky with cloud base at about 1000 feet in the assault area later in the day; these cloud conditions will continue overnight Tuesday-Wednesday. Winds will be westerly Force 4 on the English coasts and mainly Force 3 on the French coasts.

Conditions will probably continue unsettled after Tuesday and it is difficult to time further changes. But it is likely that after another front has passed on Wednesday when the 10/10ths cloud at 1000 feet lasting over Tuesday night become broken, the cloud base will increase to 2000-3000 feet through the average amount will probably remain at about 7/10ths. In this period from the passage of Wednesday's front till about Friday, beyond which no useful forecast can be given, there will be intervals of completely overcast sky with cloud base down to 1000 feet. Considerable fair periods of broken cloud can reasonably be expected between the overcast intervals. Visibility will be good throughout.

A.C.M. Tedder said that on Friday and Saturday, the effects of moist warm air coming into the Channel and producing much low stratus cloud had been prominent in the forecast presented. What had happened to clear this air from the Channel so quickly?

There had been considerable doubt about the real synoptic situation on the Atlantic over the last 48 or 50 hours. It had been considered that a front trailing from one depression now off Northwest Scotland was bent away sharply to the west into another low pressure system off Nova Scotia and Newfoundland and that this front did not extend far enough south to come through the Channel areas. This analysis had been faulty mainly because of inaccurate and inadequate reports. The front had actually swept down southeastward and crossed the northern coasts of the Central Channel in the last few hours.

In answer to other questions at this meeting, the following information was given:

- (1) There is a reasonable chance after Wednesday of further low pressure systems from the western Atlantic taking a more northeasterly course into the Iceland area instead of towards northwest Scotland; if this occurs, the fronts associated with these low pressure systems will not have such an intense effect on the wind and cloud conditions in the Channel and French Coasts.
- (2) The situation even after Wednesday must continue to be regarded as disturbed; a quiet settled spell cannot be expected to start immediately after such an intensely disturbed situation. But the time of year suggests that changes after Wednesday may be expected to be in the direction of improvement rather than of renewed or further deterioration to the present intensity.

(Following this meeting, the final and irrevocable decision to launch the assault on Tuesday morning was taken.)

0845, Monday, 5th June.

AC of S, G-3 (Gen. Bull) was informed by telephone (1) that there was nothing further to add to the forecast presented at 0415 and (2) that recent reports had shown that the clearance in cloud cover which had set in at Portsmouth in the early morning hours had not reached the area where the assault would have been taking place until at least 0600. Conditions there were 10/10 low cloud, base at about 1000 feet and had been so throughout the night. Airborne landings and medium bomber support would almost certainly have been impracticable; heavy bombers would have had no opportunity for visual bombing and aircraft spotting for naval bombardment would also have found conditions impracticable. Winds had been and continued a good Force 4 on the beaches.

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VII. Brief description of the Weather in Normandy and the Channel

(1) Period 4th to 9th June, 1944:

The two preceding Sections have summarized the meteorological advice given to the Supreme Commander and his staff about the weather likely to be experienced around the scheduled date of assault. This Section provides a summary of the main weather phenomena actually observed during the most critical period, 4th to 9th June, in the Channel and Normandy beachhead.

The summary has been compiled from notes based on reports from operational aircraft and naval vessels and on reports transmitted back by the earliest Meteorological Sections to land with the Expeditionary Forces.

Sunday, 4 June:

0100 Wind: WSW, Force 2-3.
Cloud: 2-3/10 high

0400 Wind: WSW, Force 3.
Cloud: No. low cloud over beachhead, 9/10, base 1-2000 ft. in Cherbourg Peninsula.

1000 Wind: WSW, Force 3-4.
Cloud: Variable high cloud. Low cloud on Cherbourg Peninsula dissipated to 2-3/10.

After
1000 Wind: WSW, Force 3-4.
Cloud: Small amounts over Channel and Northern France.

Monday, 5 June:

Prior
to 0400 Wind: WSW, Force 5.
Cloud: 10/10 multi-layer cloud.

0400 Wind: W, Force 4-5.
Cloud: 10/10, base 1-2000 ft.

0700 Wind: W-WNW, Force 4.
Cloud: 10/10, base 1500 ft.

1300 Wind: W, Force 3-5.
Cloud: 7-10/10, base 3-4000 ft.

1800 Wind: W, Force 4.
Cloud: 7-10/10, base 4-6000 ft. with broken cloud at 2000 ft.

Tuesday, 6 June:

0100 Wind: W, Force 3.
Cloud: 7-10/10, base 3-5000 ft.

0400 Wind: WNW, Force 3.
Cloud: 4-6/10, base 3000 ft.

0545 Cloud: Beachhead clear, with 6/10 low cloud inland.

0800 Wind: WNW, Force 3-4.
Cloud: 7-9/10, base 3000 ft., tops near 7000 ft., with 10/10 medium cloud above 11-12000 ft.

Late
Forenoon Cloud: Clouds broke and cleared over Channel.

- 1700 Wind: WNW, Force 4, 5 at times.
Cloud: Clear conditions over Channel. Variable amounts of low cloud, mainly 6-9/10 over beachhead and further inland. There was a clear area over the Seine Estuary.
- 1800 Cloud: At Cherbourg, 4-6/10, base 3-5000 ft.; at Havre, 1-2/10 low cloud, 2-3000 ft., with patchy medium

Wednesday, 7 June:

- 0100 Wind: WNW, Force 4.
Cloud: At Havre, 9/10, base 2-3000 ft.
- 0700 Wind: WNW, Force 4.
Cloud: Low cloud became more broken.
- During Day Wind: W, Force 4, decreasing to Force 3.
Cloud: Large amounts mainly 2000 ft. but 1000 ft. locally in showers at first, decreasing and lifting in afternoon. Small amounts at times later, especially near coast.
- 1800 Wind: At Havre, W-W, 2-3.
Cloud: 2-3/10.
- 1800 -
 2100 Cloud: Variable, 4-6/10, base 2000 ft. in beachhead and inland.

Thursday, 8 June:

- 0100 Wind: W, Force 3-4, Force 4-5 in Channel.
Cloud: Small amounts in Channel, 9/10 broken low cloud Le Havre base 2-3000 ft.
- 0400-
 0700 Wind: WNW, Force 3-4, Force 4-5 in Channel
Cloud: Small amounts of cloud over the Channel, 2-3/10 beachhead area, maximum Le Havre, base 3000 ft.
- Forenoon Wind: WNW, Force 4, Force 4-5 in Channel.
Cloud: Small amounts of low and high cloud, base 1-2000 ft.
- Afternoon and Evening Wind: W, Force 4, increasing to Force 6 by 1800 hours, Force 5 in Channel.
Cloud: Increasing multi-layer cloud, base of low cloud 1000-1500 ft rain beginning 1600-1800 hours.

Friday, 9 June:

- 0100-
 0400 Wind: W-WSW, Force 5, Force 6 in Channel.
Cloud: 10/10 multi-layer, base 500-1000 ft., light rain.
- 0400-
 0700 Wind: WSW, Force 3-4, Force 4-5 in Channel.
Cloud: 10/10 multi-layer cloud, base 1-2000 ft., locally 500 ft light to moderate continuous rain.
- 0700-
 1300 Wind: WSW-WSW, Force 5, Force 6 in Channel.
Cloud: 10/10 multi-layer cloud, base 1,000 ft., light intermittent rain.
- Afternoon and Evening Wind: W, Force 4, Force 5 in Channel.
Cloud: 4-6/10 low cloud, occasionally overcast, base 1-2000 ft. occasional showers.

(ii) Period 17th to 21st June, 1944:

Reference is made in Section VIII (v) to the following paragraphs on weather during this later period:

Saturday, 17 June:

0100 Wind: NW, Force 4, Force 5 in Channel.
Cloud: Overcast, ceilings near 2-3000 ft.

Forenoon Wind: N, Force 5, Force 6 in Channel.
Cloud: Overcast, ceilings near 2-3000 ft.

Afternoon Wind: N, Force 4, but Force 6 and 7 in Straits.
Cloud: 2-3/10, ceilings near 2500 ft., scattered showers.

Evening Wind: N, Force 3-4, Force 6 and 7 in Straits.
Cloud: Cleared at beachhead.

Sunday, 18 June:

0100 Wind: NE, Force 3-4, Force 4-5 in Channel.
Cloud: Overcast conditions, ceilings near 2-3000 ft.

Forenoon and Afternoon Wind: NE, Force 4, Force 5 in Channel.
Cloud: Broken, ceilings near 3000 ft.

Evening Wind: E-NE, Force 2-3, Force 3-4 in Channel.
Cloud: Multi-layer clouds, causing overcast conditions.

Monday, 19 June:

0100-
0400 Wind: NE, Force 4, Force 5 in Channel.
Cloud: Overcast conditions thickened, light rain, ceilings 1-2000 ft.

During Day Wind: NE, Force 5 and 6, Force 6 and 7 in Channel.
Cloud: Light to moderate rain persisted, ceilings below 500 ft.

2200 Wind: NE, Force 5, increasing to Force 6 and 7 in Channel.
Cloud: Broke to 9/10, rain intermittent, ceilings near 3000 ft.

Tuesday, 20 June:

0100-
0400 Wind: NE, Force 5 and 6, Force 6 and 7 in Channel.
Cloud: Multi-layer clouds cleared, and small amounts were observed.

0400-
Forenoon Wind: NE, Force 5 and 6, Force 6 and 7 in Channel.
Cloud: Stratocumulus cloud cover developed, ceilings near 1000.

Forenoon and Afternoon Cloud: Cloud deck persisted in forenoon but broke to small amounts during afternoon.

after 1800 Wind: ENE, Force 6, NE, Force 6 and 7 in Channel.
Cloud: Low cloud deck re-formed, ceilings near 1000 ft.

Wednesday, 21 June:

0100-

Afternoon Cloud: Overcast conditions, ceilings between 500 and 1000 ft.

Late

Afternoon Wind: NE, Force 5 and 6, NE, Force 6 in Channel.

Cloud: Small amounts of cloud.

VIII. Review of the military decisions as affected by the meteorological advice.

(1) Earlier sections of this report have summarized the procedure adopted for providing meteorological advice, particularly weather forecast advice, to the Supreme Commander and his Staff; a summary of the forecast actually presented has been given (Sections V and VI) and also a synopsis of the weather as it actually turned out to be (Section VII).

Technical details relating to (a) the weather situations and its developments during the critical period, (b) the views expressed by the forecasting centrals, which took part in the meteorological conferences, and (c) some of the problems of forecasting which were encountered during that time - these have been relegated to Appendices A, B and C respectively.

So far as the general Report is concerned, it is desirable at this stage to consider some of the implications of the meteorological advice and the alternatives which might have been adopted. Those matters are reviewed in the following paragraphs.

(11) General and Preliminary Decisions.

Apart from the fact that the scheduled date for launching the assault was set early in June, and not in May or July, a decision which may well have been influenced much more by military necessity than by information of the type referred to in Section II, the main facts from the meteorological point of view are:-

- (1) that the scheduled assault at 0630 on Monday 5th June was deferred on a day-to-day basis from Monday 5th June to Tuesday 6th June, on a weather forecast given 30 hours before the scheduled time of the landings, and
- (2) that the decision to proceed with the assault on Tuesday 6th June was taken on a forecast presented on the evening of Sunday 4th June.

It is true that decisions had been taken on May 28th and 31st and June 1st which involved the sailing of naval bombarding forces and the more distant assault Forces, and that those decisions were at least partly influenced by meteorological advice; but it had been made clear that those Forces would not be allowed to sail on the scheduled dates in advance of D Day only if the meteorological advice was that conditions eight days ahead (in the case of the forecast on 28th May and correspondingly shorter periods for May 31st and June 1st) would be prohibitive for the assault in the Channel area and Normandy coast by reason of continued gales or continuous low cloud.

In the circumstances of the weather situation at the time the probabilities were against such contingencies, and the Supreme Commander was advised accordingly (see Section IV).

Decision to defer from 5th to 6th June.

As regards the decision to defer the assault, made provisionally on Saturday 3rd June and confirmed early on Sunday 4th, mainly on a forecast of likely conditions in the central Channel and Normandy areas from 0001 hrs on Monday, the description of the actual conditions given in Section VII(1) shows that cloud conditions were continuously overcast and wind was Force 4-5.

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Those conditions continued till at least 0600 on Monday and the improvement thereafter was slow and irregular. It was not till well into the forenoon of Monday that low cloud began to break to any operationally useful extent; wind remained fresh in the beachhead area until the evening of Monday.

It is therefore fairly certain that the weather conditions in Normandy during the crucial hours immediately before and at the scheduled time of launching the assault were prohibitive, at least from the points of view of airborne troop landings, and the actual landings on the beaches; the heavy bombers would have had to operate by non-visual technique and the medium and fighter bombers would have been seriously hampered. Aircraft spotting for naval bombardment would probably not have been practicable.

(iii) Decision to proceed on 6th June.

As regards the decision to proceed with the plan after 24 hours' postponement on the basis of a meteorological forecast presented on Sunday evening, 4th June, Section VII (a), shows that the actual conditions in the hours immediately preceding and following the time of landings, though not the ideal or even the complete minimum requirements, were decidedly better than those on the preceding and succeeding nights.

The surface wind, and therefore the sea roughness, had moderated during Monday evening; and the amount of the cloud and the height of its base at various times of the night and early morning were such as to allow all phases of the assault to be carried out according to plan.

In particular, the conditions for airborne landings were somewhat better than forecast in that the cloud ceiling was at the unusual height of 4000-5000 feet; and by the time the heavy bombers were due to operate, the cloud was sufficiently broken to allow use of visual technique. The medium and fighter bombers were not hampered, nor were the spotting aircraft. The wind conditions on the beaches were within the limits set, though the sea and surf still suffered from the stronger winds of Sunday and Monday.

That the weather deteriorated again during Tuesday and continued poor into Wednesday could not have surprised the Supreme Commander and his Staff; considerable emphasis was put on this deterioration at the meetings leading to the final decision (Section V).

(iv) Possible alternative decisions.

It should be mentioned that the Supreme Commander's meteorological advisors gave much consideration on Sunday, 4th June, to the question of whether conditions for an assault on Tuesday, 6th June would be more or less favorable than on Thursday, 8th June. They understood that as the assault forces from greater distances were already at sea, at least a proportion of them would require to return to base for about 12 hours if decisions went against launching the assault on Tuesday. This would preclude a Wednesday assault.

In this connection, the alternatives from the meteorological point of view were

- (a) a reasonable confidence in a favorable interval, even if of limited duration, just preceding and at the time of an assault on Tuesday,
- (b) less confidence in an only possibly better interval on Thursday morning.

Keeping in mind the extent to which the whole weather situation had so quickly and intensely been disturbed since Thursday, 1st June, and the proneness of disturbed conditions to continue once they had started (particularly when that start had been so violent for the time of year) it was considered that the alternative (a) should be emphasized

in the advice given to the Supreme Commander. If in fact the conditions turned out so that Thursday, 8th June, would have been a better day for the assault, then those conditions would be equally valuable for the immediate follow-up phase of the operation. Whereas, if the opportunity of favorable conditions overnight Monday-Tuesday were missed, and if information on Monday and Tuesday showed that Thursday would be less favorable than it seemed on Sunday, then the whole position would have become extremely serious from the viewpoint of holding us such a huge and complex operation.

As matters actually turned out, the weather overnight Wednesday-Thursday (7th and 8th June) was probably not quite as good as the weather from midnight on Monday 5th to early Tuesday 6th June, and during Thursday wind increased to Force 6 accompanied by multilayer clouds and rain; by evening, winds were mainly Force 6. These conditions continued throughout Friday with overcast skies of multilayer cloud, base at times down to 500 feet.

The weather throughout the whole period from 3rd June to at least 22nd June (when these notes were written) remained unsettled with intermittent spells of strong wind and cloudy to overcast skies.

(v) Weather a fortnight after the scheduled date for assault

Although the deliberations at the meteorological conferences did not explicitly take into account the contingency of the assault having to be postponed beyond a few days from the scheduled date of 5th June, it is of interest to look briefly at what the sequel might have been had the Supreme Commander found it impracticable to decide on a date in the first batch of possible dates, viz. 5th to 8th June.

In this contingency, it is likely that for other than meteorological reasons the operation would have had to be postponed for a 12-14 day period.

Section VII (ii) shows that the early hours of 17th June would have been favorable for the actual assault and its associated operations, but the immediately following days would have been prohibitive for the follow-up and early build-up phases. Force 5 winds with Force 6 and even 7 at times from a northeasterly direction with long periods of overcast sky and low ceiling (1000 feet or less) would have seriously hampered all naval and most air operations, as indeed they did, though at a somewhat less critical stage of the operation.

IX. Comments and Recommendations

1. General

The following paragraphs summarize some of the more important impressions and views derived from taking part in the meteorological arrangements and in the presentation of forecasts and information. The comments are not offered in any sense of criticism; they are included in this report primarily in the hope that they may be of use in any similar circumstances that may arise in the future.

From the viewpoints both of the procedure adopted for obtaining the meteorological advice, and of the complexity of the operation for which the advice was given, the arrangements were probably unique; it is therefore not surprising that the arrangements were not perfect. But the experience gained should be of value for the future and it is the aim of this Section to indicate along which lines improvement might be sought.

2. From the Military Point of View

(a) Information on Operational planning made available to Meteorological advisors.

The Meteorological Section was not set up at Supreme Headquarters until a considerable time after the initial plans for the operation had

been made, but facilities were provided for the Section to become conversant with whatever details were necessary for giving meteorological guidance in the later planning stages. Besides access to relevant papers opportunity was given for discussion with the planning authorities.

This latter aspect is important in all military operations. With a technical and complex subject like meteorology, written statements (or "appreciations") about likely implications of meteorological factors on an operation are a very poor substitute for oral discussion with the appropriate authorities.

From the viewpoint of the operational staff such discussion allows the meteorologist to explain the implications and significance of aspects of meteorological information which are liable to be overlooked and at the same time care can be taken to ensure that unwarranted emphasis is not attached by the operational staff to weather statistics.

From the opposite angle, the meteorologist learns by discussion much better than by paper statements which aspects of weather at which precise times are most important from the operational standpoint and so can give more effective advice whether it be in planning or in decisions on actual operations.

A case in point was the airborne part of the NEPTUNE operation. According to the requirements as set out in Section I(b) a cloud ceiling of 2500 feet had been accepted as the minimum along the route from base to target and over the target area. But on the 3rd June when it became fairly certain that cloud conditions were likely to be poor on the night of the 4th-5th, discussion with the ultimate authorities elicited the information that airborne landings might be effectively made with a 10/10 cloud ceiling at or even somewhat below 1000 feet.

(b) Elasticity in selection of D-Day

With the magnitude, range and complexity of the military and political factors concerned in the NEPTUNE operation, elasticity in decision must necessarily be limited. Even such details as tides, light and clearance of under-water obstacles practically pre-determine when such amphibious operations must be launched. Nevertheless NEPTUNE was deferred one day and would doubtless have been further deferred had weather prospects justified it.

The inference is that no matter how complex the operation is, plans should always allow for a postponement because of weather. In the last resort the success of the initial landings and therefore of the whole operation is determined by weather conditions allowing effective co-operation of all arms.

(c) Rehearsal of procedure involving meteorological advice leading to military decisions.

As has been described in Section III, the Supreme Commander's Staff arranged for meteorological briefings for dummy D-days to be given in the weeks preceding the actual operation. It was realized that the actual making of the final decision, taking into account the likely weather conditions, was an important phase of the whole operation.

This was an effective and profitable innovation in military operations and one that should be followed in similar operations in the future. It might have been even more profitable if the weather in South England and the Channel in the weeks before the invasion had not been so consistently good. For the complete break in the weather at the time when the real decision had to be made introduced complications which could hardly have been provided against with the blue skies and light breezes which formed the background of most of the rehearsals.

3. From the Meteorological Point of View

(a) The procedure for obtaining the agreed Meteorological Advice

There are inherent defects in the kind of meteorological procedure

adopted for the NEPTUNE operation. So long as accurate weather forecasting involves a subjective analysis and interpretation of observational data with a blended background of experience and technical knowledge which necessarily varies with each individual forecaster, so long will forecasting centrals with the same basic data produce different forecasts of future weather.

Such differences in interpretation and analysis cannot adequately be resolved by telephone conferences, however frequent. Aids such as facsimile reproduction processes for synoptic charts might reduce some of the differences by ensuring that each of the advising Centrals realizes clearly what different premises the other centrals are using for making their forecasts. But in the circumstances described in Appendix A where it is shown that interpretation of a report from one ship was all-important, it is doubted whether an interchange of each other's synoptic charts by facsimile process would have helped. As in the meteorological conferences at that time, each Central would naturally adopt the interpretation which best fitted its general trend of analysis.

Another aspect of this same matter is the drawback arising from the need for achieving and disseminating an agreed forecast for coordinating the meteorological advice at operational levels. As soon as a main decision is made for starting complex operations of the NEPTUNE nature, instructions are issued to the various force commanders, Naval, Air and Ground, both U.S. and British, to proceed with the execution of the plan. It is therefore necessary that the meteorological advice given to those force commanders does not conflict with the advice on which the primary decision has been taken. This necessitates that each of those advisors be provided with a statement of the forecast on which the advice to the Supreme Commander has been based, and this in turn requires that the outcome of meteorological conferences on which the Supreme Commander's advisor has based his views be framed in strict meteorological terms.

Now it is one thing to convey orally a description of future weather, stressing aspects that are essential and minimizing others sufficiently to allow decisions to be made; it is another thing to commit such advice to paper in a way which will be useful to meteorological advisors at specialized operational formations. To be of any value to such advisors, the statement requires definition of the timing of weather sequences, the intensity of the accompanying weather, the specific localities affected and so on. And to get a number of forecasting Centrals to agree to such a detailed statement on occasions when, for example, passage of fronts cannot be accurately timed, either means that only one of the Centrals' advice must be taken, or that the statement must be so worded for acceptance by all the Centrals as to be of little value to the meteorological advisors at operational formations.

It is not clear what the solution to this difficulty may be for future operations of this kind. One solution might be to establish one Central at which the best qualified and experienced representatives of the various meteorological services concerned work together instead of in separate institutions connected only by wires; it would be agreed beforehand by the various services concerned that the forecasts issued by that Central would be accepted by all the services involved in the operation. This kind of arrangement is known to function on the military side, but whether meteorological services could be fitted into a similar framework is questionable.

A second solution might be found on the lines of restricting the function of the conferences solely to providing an exchange of views about analysis and future trends and developments; there would be no responsibility at the actual time of the conference on the part of the chairman to find an agreed development and forecast acceptable to all the participating Centrals.

With the views of the Centrals in mind, the Chairman would use his own discretion as to which, if any, of the sets of views offered he would adopt as the basis of the advice to be given to the Supreme Commander and also to be used in framing coordinated forecasts for distribution to the meteorological sections at operational formations.

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(b) The value of long range forecasting in military operations.

Reference has been made elsewhere in this report to the accuracy of forecasts for more than 24 or 36 hours except in stable weather situations. cursory examination of the series of 5-day forecasts submitted to the Supreme Commander and his Staff during April and May, 1944 has shown that even in the rather abnormally stable weather circumstances of those months, the operational value of forecasts fell away quickly after the second or third days after the issue of each forecast; when the synoptic situation was changing rapidly, the forecasts frequently required substantial modification before the first day was past. If specific details of cloud, wind and visibilities for limited areas had had to be included in each forecast, even this 24-hour period might well have been too long in some types of English weather.

Although every effort should therefore continue to be made by the various Meteorological Services in improving their several techniques for extending weather forecasts beyond 24 hours, it has to be appreciated that at the present time forecasts in sufficient detail to be of operational (as distinct from planning) value can seldom be made with useful confidence for more than a 24-hour period in advance.

For assistance in planning, statements can be made to the effect that "weather is likely to continue to be unsettled with considerable general cloudiness though with intervals of well-broken cloud and good visibility", or, in more exceptional circumstances, that "mainly settled weather will persist for next few days with light, moderate northwesterly wind and well broken cloud, minimum at night". But the discovery of a technique by which even first approximations to such details of weather as are required for specialized operations can be forecast as a regular daily procedure with useful accuracy for any day more than two or even more than one day ahead still remains a matter for future research.

APPENDIX A (Set)

Description of the Synoptic Meteorological Situations and Their
Developments over the Period 1st to 6th June 1944

1. Introductory Remarks.

The material in this Appendix and Appendices B and C is primarily of technical (meteorological) interest. The aim in compiling these Appendices has been to reconstruct some of the problems with which the Forecasting Centrals were confronted during the critical phases prior to launching operation NEPTUNE.

The paragraphs which follow contain a suggested post facto analysis of the weather situation covering the period of operational interest. Though every care has been taken to utilize every piece of evidence in reconstructing the situations, the analysis is not necessarily a final statement capable of acceptance by all the meteorological authorities; it is primarily intended for consideration in conjunction with the forecasts offered to the Supreme Commander and his Staff (Sections V and VI) and secondarily for appreciating the difficulties with which the forecasting Centrals contended during the conferences summarized in Appendix B.

Particular mention should be made at this stage of the vital assistance in the analysis and forecasting provided by ships which had been assigned to predetermined locations in the Atlantic by the United States Navy and the British Admiralty. The United States Navy augmented their regular complement of six ships by two additional ships for the critical period. These eight ships operated mainly west of 30°W. The British Admiralty provided two ships from Day D-7, one to function between 20 and 25°W longitude, due south of Iceland and the other in a similar longitude north of the Azores.

2. General Comment.

Some of the main difficulties of analysis are referred to as they arise in subsequent paragraphs; they were such that at the time it was possible for the forecasting Centrals to differ from each other by as much as 10 mbs. in their interpretation of the pressure in an important area, and even after the event it is difficult to place much confidence in any reconstructed chart.

The critical developments took place in the area bounded approximately by 55°N-60°N and 15°W-35°W between the early hours of the 2nd and midnight of the 4th. The western section of this area (25°-35°W) is normally an "empty" area from the viewpoint of reports; normally, the eastern section is at least partially covered by the "Bismuth" meteorological reconnaissance flight, and during the time of the operation a ship reported from the area between 22° and 25°W, and 52° and 59°N.

When movement and development is rapid, the interpretation of reconnaissance flights is a matter of considerable difficulty; past experiences have led the majority of forecasters to treat aircraft pressure reports with great caution. In the event the reports from the single ship became all important, and it is greatly to be regretted that at the critical time (from both the synoptic and operational viewpoints) very substantial doubt was introduced into the definition of the situation by a jump of 20 mbs. in reported pressure; this was repeated in the next observation then, and the discontinuity followed. In addition, the ship began its southward run on the 2nd, and was to the south of the area of maximum development on the 3rd and 4th. When this is considered in conjunction with the somewhat unreliable reports to the south of Greenland on the 1st, there can be no surprise at the existence of considerable differences in analysis between the Centrals.

It should also be remembered (a) that the period under consideration followed a long spell of mainly anticyclonic conditions and (b) that during the period when the main decision had to be taken a situation developed which can only be described as very disturbed even by winter standards.

The charts (reproduced as Figures 1 to 7) which have been prepared for use with the following notes represent the reconstruction by the Meteorological Section, SHAEP, of the main essentials of the synoptic pressure distributions during the period 1st to 6th June. The series of charts used by each Central at the time probably differed in greater or less detail from Figures 1 to 7.

2. (continued)

Upper Air Contours.

Figures 8 to 11 are included for the purpose of indicating the general nature of the upper air circulation on 5th and 6th June. In those figures the bold continuous lines are pressure contours drawn for each 200 feet; the thinner dotted lines are isotherms (5°C) and the very thin continuous lines confined to the British Isles and immediately adjacent areas are "thickness lines" in 200 feet intervals between the 750 and 300 mb. levels. Short heavy arrows represent flow of cold air between the levels of 750 and 300 mb. and the short skeleton arrows do the same for warm air. Arrows connecting encircled courses indicate trajectory of the associated systems, and black arrows with W or K show advection of warm or cold air at the 500 mb. level.

The figures 8 to 11 have been supplied by the Director United States Weather Services to whom acknowledgement is made for permission to reproduce them.

3. Analysis

At 0100Z on 1st June, a complex low pressure trough extended from a shallow centre to the west of Scotland (11) southeastward over the British Isles. A cold front lying north to south over central France was moving east. Pressure was high in the Jan Mayen region with a flat ridge down to the North Sea. A ridge from an anticyclone centered over the Azores extended into the south of the Bay of Discay.

A complex depression east of Newfoundland (12) was moving northeast, and a further depression (13) was forming in the St. Lawrence region.

A wave disturbance (14) with no closed centre but with very warm moist air in its warm sector to the northeast of Bermuda was moving northeast (Fig. 1).

The 500 mb chart showed a centre to the south of Greenland, with a col between Iceland and Scotland. The air between Greenland and Iceland was warmer than that immediately to the south, with cold air over Scandinavia. There was a strong west southwesterly flow from southeast of Newfoundland to the col, and strong easterlies over south Greenland.

During the 1st, 11 moved east towards northern Scotland, and cold air from northern Scandinavia moved westward on the southern side of the Jan Mayen high, with the formation of a col at the surface and at 500 mb to the south of Iceland.

2nd June

It seems probable that a trough from 12 developed to the east with the main centre following more slowly (at 20-25 mph) on an east northeasterly track; but the detail in this area is obscure owing to the corrupt and conflicting nature of the few reports available in the area south of Greenland. The depression has a complex history and seems to have had two separate centres at 0100 on 1 June. However, a front (probably the occlusion of 12) passed the ship in $57^{\circ}\text{N } 24^{\circ}\text{W}$ between 0100 and 0700 on the 2nd. There is also little direct evidence of the progress of the tropical air in the wave 14; but at 0900 hrs. it had reached the ship at $51^{\circ}\text{N } 32^{\circ}\text{W}$. In this vicinity it would come under the influence of the cold front of 12, and by 1300 on the 2nd it is probable that a complex wave was forming in the region $50^{\circ}\text{N}, 30-35^{\circ}\text{W}$. In the meantime, 13 had moved into a position east of Newfoundland. (Fig. 2).

The 500 mb chart on the 2nd showed a very strong west southwesterly sweep from south of Newfoundland to Scotland, with the warmer air between Greenland and Iceland being displaced by colder air from the east and an elongated col from south of Iceland to south Norway. Conditions has then become suitable for cyclonic development in the region between Iceland and Scotland.

Developments in the 24 hours after 1300 hrs. on the 2nd are difficult to follow, particularly in view of the nature of the reports received from the ship in about $55-57^{\circ}\text{N } 25^{\circ}\text{W}$. There is some evidence that the pressures reported by this ship were for a time low by an amount of the order of 5 mbs. but this is not certain. The confusion was increased by a jump of 20 mb in reported pressure from the same ship at 0300 on the 3rd; this discontinuity was maintained by the 0600 report but had disappeared by the time the 1000 report was received.

At 1300 on 2nd June, the diffuse warm front of L2 had spread into west Ireland, and pressure was falling in the region 25°W, where the wave L4 was approaching the trough of L2, resulting in a low pressure area of complex frontal structure.

3rd June

The cold front of this depression appears to have passed the ship at 55°N 22°W between 0100 and 0300 on the 3rd, but there was no appreciable rise in pressure and the front does not appear to have passed far south of this point before returning as the warm front of L3. The ship was again in warm air by 1600 hrs on the 3rd.

* See Figs. 1 to 7 for positions of pressure systems identified by symbols in these paragraphs.

In the meantime, cold air had been spreading south to the east of an anti-cyclone in the Hudson Bay area and the eastward movement of colder air to the south of Greenland had continued. The result was the establishment of an intense west-southwesterly gradient at 500 mb. from Newfoundland to Scotland with a flat area from Labrador to the Faroes. In this intense gradient the system L3 appears to have moved quickly east, the cold front progressing at about 40 mph, passing a ship in 51°N 33°W between 1300 and 1600 on 3rd June. During this rapid movement, the centre would not be expected to deepen appreciably and a trough would probably be left in about 55°N to 60°N. The very moist warm air of L4 had spread into the west of Ireland by 1300 on the 3rd, and the considerable pressure falls in this region which had first appeared on the 0100 chart continued after the passage of this warm front.

During the 3rd the depression L6 formed in the region of Nova Scotia; and, drawing polar air from the Hudson Bay anticyclone, began to deepen very rapidly whilst moving ENE. The suggested position of low pressure systems and major fronts at 1300 on the 3rd are shown on Fig. 3.

4th June

The rapid easterly motion of L3 and the deepening of the complex system L5 continued, and the cold front of L3 passed the ship at 52°N 20°W between midnight and 0400 on the 4th, and was over Ireland by 1300 hrs. By this time the circulation of L3 had combined with L5 and the centre was moving more slowly. There had been considerable deepening late on the 3rd, which continued on the 4th. A suggested analysis for 0100 hrs. 4th June, is shown on Fig. 7, with tracks of the low pressure systems.

During the 4th June, the cold front of the combined depression L5 continued to move across the British Isles, with an average speed of about 30 mph, whilst L6 deepened very rapidly indeed, with the centre slowing and moving NE or N. This simultaneous deepening of L3 and L6 was a most remarkable development. The strong westerly flow at upper levels was distorted by the two deepening and occluding depressions and an intense NW'ly gradient developed at upper levels to the west of the British Isles. A very sharp and deep upper air trough moved over the country, the trough line being about 400 miles behind the surface cold front of L5 on the 5th, and rises of pressure at the surface were inappreciable until the upper trough line had passed.

5th June

The frontal system of L6 was carried forward to the south of the centre, which continued to move slowly NE on the 5th. The surface warm front was carried forward almost to the ridge line, over which there was a fairly strong gradient at all levels. In these circumstances no building of the ridge could be expected, and pressure in the col between L5 and L6 probably remained at about the same level (1010 mbs.) throughout. L5 probably attained its maximum depth about 0100 hrs. on the 5th when it was estimated at below 975 mbs. in 60°N 5°W. It was moving very slowly East, and by 0700 hrs. was filling rather rapidly.

By 1800 hrs. on the 5th, L6 had reached its maximum depth, a pressure of 975 mb. being reported near the centre at 55°N 45°W. The col was then in the neighborhood of 60°N 22°W and the centre of L5 just north of the Shetlands. By this time warmer air had been carried well round the north of L5, isolating a pool of colder air in the eastern North Sea. Rises in this region were small, and the tendency for a

southeastward transference of the centre of lowest pressure was obvious by 0700 hrs. on the 6th; a gradient of 25-30 mph. from the northwest was maintained over the Channel area throughout the 6th by this means. The surface warm front of 16 had been carried forward to the ridge line, and its outward movement had ceased by 1300 hrs on the 6th. Thor upper winds over Western England and the Channel during the 6th reached a speed rare even in disturbed winter conditions.

APPENDIX B

Summary of views of the Forecasting Centrls as expressed at the Meteorological Conference held from 1st to 6th June.

1. Introductory Remarks.

(a) Sections 2 to 4 of this Appendix summarise in the form of brief notes the views of the three forecasting centrals on synoptic developments covering the period of decisions for launching the assault; they are based on notes made hastily during the meteorological conferences by telephone. The Figures 1 to 7 referred to in the notes and the nomenclature adopted for the various pressure systems are as described in Appendix A, particularly Section 2.

(b) Although the series of synoptic charts reproduced as Figures 1 to 7 are referred to in the brief summary of analysis in Section 2 as if they constituted the single and unique series of charts which each central used at the time of conferences, the charts are post facto reconstructions prepared by the Meteorological Section SHAEF; each of the Figures 1 to 7 is known to differ in greater or less detail from the actual working charts used by the centrals at the time of the conferences.

These differences naturally have important bearings on the significance of the views expressed by the Centrals as briefly summarised in Section A below. To do complete justice to each Central it would have been necessary to reproduce three sets of charts, one from each central. But early enquiry with this in view made it clear that it would not be practicable to obtain reproduction of the charts exactly as they were when the discussions took place.

It was therefore considered that the best course was to draw one independent set of charts using all the later data and subsequent history of developments; it was realised that this set of charts in all probability would not be accepted by any of the centrals and would make the analysis as summarised below appear too pessimistic or too optimistic. But it would serve the purpose of illustrating the general trend of development as envisaged by the centrals.

(c) Another aspect of the conferences should probably be kept in mind in reading the summary of analyses. The conferences were hardly ever shorter than one hour and sometimes extended to almost two hours; it cannot therefore be expected that the views expressed by the centrals can be adequately compressed into a very brief summary. Further, that central which opened the conference - the opener changing in rotation - generally presented a comprehensive analysis, and the presentations of succeeding centrals were mainly confined to emphasising points of difference. It therefore comes about that the summaries of the analyses tend to lay undue stress on differences of opinion and make little or no mention of those important aspects of the analyses which were more or less agreed by all the centrals.

(d) Little mention has been made in these notes of the actual forecasts of weather in the Channel made by each central; it is, however, probably a fair summary to say that Dunstable expected a westerly flow into the Channel area of the moist humid type of air, with a high average cloudiness and low base height. These conditions were forecast to return after a brief interval when it became clear that the cold front would pass through the area. For the whole of the period, Widdow, on the other hand, tended to minimise cloud amounts and wind strength in the Channel, basing their argument on the maintenance of relatively high pressure from the Azores to North France, with the moist humid air being carried further North. When it became clear that the cold front (of 13) would cross the area, the view was unchanged as a wedge development was expected behind it. The Admiralty central generally maintained a view midway between the two.

2. Brief Summary of Central's Analysis.

Evening, 1st June.

Dunstable:- I1 is expected to move east and deepen; I2 coming out at 60°N to into frontogenetic region lying east to west in 60°N to north of Scotland. Generally cloudy westerlies in Channel area. Lows not intense. Agreed that there would be a tendency to fill as lows moved south of Iceland, and regenerate in Norway region.

Widewing:- Strong upper easterly airflow over south Greenland is preventing rapid eastward movement of lows. Azores ridge building up to north and northeast. I1 moving east and deepening. Anticyclonic conditions will develop later in Channel areas.

Admiralty:- I1 expected to move east-southeast and deepen. Ridge building temporarily behind it. I2 probably held in west Atlantic, but perhaps moving east, filling slowly, followed by I3, bringing cold front through Channel on 6th June.

Morning, 2nd June.

Dunstable:- Situation deteriorating with strong westerly flow developing aloft, I2 less deep but coming through, followed by I3. (Cold air from Scandinavia area spreading west and replacing warm air to the southeast of Greenland.) The result expected would be a fairly vigorous westerly type of weather but with cold fronts not reaching Channel area. Warm air with much low stratus in Channel.

Widewing:- Azores pressure rising and I2 filling. Cannot agree that westward spread of cold air from Scandinavia will favour eastward passage and deepening of I2. Warmest moist humid air on Atlantic spreading east, into northwestern districts of the British Isles, but not affecting the Channel area, which is expected to have little cloud.

Admiralty:- No change of view. Sluggish movement of shallow depressions from west for some time; slightly more pessimistic than yesterday.

Evening, 2nd June.

Dunstable:- Situation more obscure. Depressions on Atlantic not intense, but danger of intensification in region between Scotland and Iceland. Small system with tropical air to northwest of Azores (I4) moving northeast. Channel area in flow of moist warm air round the Azores high with falls of pressure to the northwest causing winds to back sufficiently to push low stratus cloud up Channel.

Widewing:- I3 not expected to move east rapidly. Azores ridge expected to be oriented in a more northeast-southwest manner than hitherto, with axis extending into the Channel area until 5th; at later stage the wedge axis will retreat south. No fronts coming through Channel during the critical period.

Admiralty:- Still expect I2 to move east as a feeble system in about 60°N with following systems taking a more northerly track as Arctic anticyclone is transferred slowly westward to Greenland. Not hopeful about cloud conditions for 5th, as light westerlies are expected in Channel.

Morning, 3rd June.

Dunstable:- Some clarification. Frontal zone from Nova Scotia to northwest Scotland with wave in mid-Atlantic coming across (I4), followed by I3. Polar air behind I3. Warm moist air still expected in the Channel area during the period.

Widewing:- Holding to previous ideas of development. Although pressures are falling in Ireland, pressure still rising at upper levels to the West. (Epicure ascent.) Upper rises from the west; on extrapolation, these rises come into British Isles in 24 hours' time. Falls of pressure occurring in Ireland are due to approach of warm front of I2. No cold air to intensify the system so ridge expected to build behind this front. Conditions expected to be 5/10 cloud or less through Wednesday in Channel areas.

Admiralty:- No change of view.

Afternoon, 3rd June.

Dunstable:- Great reservoir of polar air in the north from Russia to Canada but no indication of break through except behind I6. I6 will move eastward and should be near Scotland on Wednesday morning. After warm front of I5 has gone through Channel area tomorrow, Channel will be in WSW air flow of moist humid air, until Wednesday.

Widewing:- I5 moving east. I6 moving northeast, then slowing and moving into Denmark Strait absorbing I3. Fronts of I6 coming through, perhaps with minor development at point of occlusion. Cold front of I5 coming through but inactive south of 52°N. Main cold front of I6 possibly retarded by further wave development. Flat ridge crossing British Isles ahead of fronts of I6; ridge line will be over North Sea on the 6th.

Admiralty:- Situation still borderline. I5 slowing down moving NE (pressure falling in southern Ireland). I3 not important; but ENE movement of I6 will be rapid with outbreak of cold air behind it. Possible that cold front may come through our areas before cold front of I6.

Evening, 3rd June.

Dunstable:- Similar to morning analysis. Situation becoming unpleasant. Complex low to south of Iceland (I5) moving east. Cold front estimated just south of 54°N at 0700 hrs. and not expected through Channel area as I3 would follow I5 eastward across the Atlantic, followed in turn by I6. Cold front coming through behind I6 probably on 7th or 8th. Tropical air in Channel area during the period 5th to 7th.

Widewing:- Immediate development will be I5 moving east-southeast into North Sea, with active cold front through the Channel on 4th-5th. I3 and I6 moving to south of Iceland with cold front of I6 reaching British Isles on the 8th.

Admiralty:- Small low near northwest Scotland (I5), with associated wave running ESE across Scotland, expected to move east-southeast; low I3 slowing down and moving northeast. Atlantic ship reports not showing substantial falls. I6 will have cold outbreak behind it and probably move into and absorb I3, the combined centre eventually moving into the Norwegian Sea. Tropical air from I4 still well to west but reaching Channel area on the 4th. Possibility indicated that cold front of I5 will come through, but this was discarded later in the evening. Azores ridge expected to move southward and weaken with first cold frontal passage (front of I3) on 7th and another (cold front of I6) on 8th.

Morning, 4th June.

Dunstable:- Little change in picture. Cold front of I6 will move to west of Ireland on 6th, trailing into the Channel area on Wednesday, 7th. Centre of I6 might be held back in western Atlantic.

Widewing:- Expects axis of finger of high pressure Azores-North France not to move much, but some decrease of its intensity is indicated. Broad southwesterly flow on Atlantic with zone of activity far enough to northwest (Cape Hatteras to 60°N 10°W) to allow of good conditions in Channel.

Admiralty:- I1 and I3 have combined and will continue to deepen. Ridge from Azores to Discay weakening in east and will allow fronts to come through. I6 moving rapidly east at the moment and cold front may be through Channel early 7th. Deterioration in situation supports more pessimistic parts of previous analysis.

Afternoon, 4th June.

Dunstable:- Cold front of I5 well to south, position not known, but not south of 48°N in 30°W. Doubtful of development of wedge between I5 and I6 as reports in this region are conflicting. Still consider I6 will continue to move east with I5 moving northeast fairly slowly. Cold front of I5 passing through Channel areas on 5th but trailing across France. Strong front (warm front of I6) well forward into Atlantic wedge so ridge effects should be minimised.

Widewing:- L5 moving northeast. L6 moved into Denmark Strait area, with fronts approaching Ireland on Wednesday. Mainly flat wedge conditions over Channel area with temporary deterioration at front of 8th.

Admiralty:- L6 moving into Denmark Strait. L5 moving northeast. Atlantic wedge building slightly and coming in, but remaining flat. Occlusion of L6 in west Channel on 7th, with good wedge behind.

Evening, 4th June.

Dunstable:- L5 not expected to have passed Shetland on the 5th, therefore still expect L6 to move east, not northeast. Ridge between L5 and L6 weakening. L5 moving northeast to Norway coast on 6th, and filling. L6 south of Iceland Tuesday morning, with wave on cold front. Disturbed conditions after 6th.

Widewing:- L6 expected to move NE so that by midday 5th June its centre will be about 59°N 35°W with 980 mbs. centre, and by midday 6th June at 64°N 35°W with 990 mbs. centre.

Admiralty:- Cold front of L5 through area early 5th, linking back through flat wedge to warm front of L6. L6 expected to move into Iceland area and fill. Warm front of L6 near Scillies by 1300 hrs. 6th, moving east slowly. Cold front of L6 through Channel area on 8th or 9th.

Morning, 5th June.

Dunstable:- Now agree that L6 not moving east as anticipated, but wedge in advance of centre has front across it and will not build any more. Warm front of L6 expected to move into west Ireland by evening of 6th.

Widewing:- Situation as anticipated. L6 not moving East. Wedge between L6 and L5 is building; fronts as anticipated on the 4th.

Admiralty:- L5 moving very slowly. L6 moving north but fronts coming through British Isles. Warm front reaching west Ireland by evening of 6th. Wedge between L5 and L6 not pronounced but building a little.

Afternoon, 5th June.

Dunstable:- No material change of view. Warm front in the assault area about mid-day on 6th. Extensive cloud under inversion in wedge which is not expected to build up. (Front has moved forward almost to wedge line.)

Widewing:- L6 stationary. L7 moving into it and eventually into Davis Strait and low pressure at point of occlusion of L6 moving slowly east-northeast, then northeast. Large anticyclone to east and west of Azores with flat ridge over west Atlantic and British Isles. Effect of frontal passages British Isles minimised.

Admiralty:- Little change in view from morning. Warm front of L6 expected in assault area about mid-day 7th. Cloud breaking in wedge during night of 5th-6th.

Evening, 5th June.

Dunstable:- L5 filling, moving very slowly northeast. L6 moving slowly northeast with L7 moving into it. No change of cloud forecast.

Widewing:- No change.

Admiralty:- L5 filling and moving slowly northeast. Azores high moving east-northeast with ridge building again over France. No change in timing warm front of L6. Finds less than Force 4 in Channel.

Morning, 6th June.

Dunstable:- Little change. L5 now stationary and warm front of L6 retarded somewhat.

Widowing:- Still substantially same analysis. Expect warm front of L6 will dissipate south of 51°N. Cold front expected 8th or 9th.

Admiralty:- No substantial change but warm front retarded somewhat.

APPENDIX C

Notes on the Problems of Forecasting, 1st to 6th June

1. General

It has been explained in the preceding Appendices that the principal forecasting problems arose from the difficulty of analysis of each current forecast chart in the series. Even in retrospect this is not surprising. A part from the obscurity of the actual pressure distributions over the most important areas of the Atlantic, the general level of activity rose rapidly over the most critical period to a level far above the normal, even for disturbed conditions in summer.

The pressure reading of 976.8 mb. at Wick at 0400 on 5th June was probably the lowest June reading on record in the British Isles. The previous lowest, 978.3 mb. at Malin Head on 11th June 1926 was recorded in the Meteorological Magazine (Vol. 61, p.155) as the lowest for at least half a century. This makes the 5th June 1944 reading the lowest for at least 68 years and probably the lowest on record.

Apart from this isolated pressure, a search through the synoptic charts of the last forty years has shown that during this period there has been no situation of similar intensity (two depressions with centres below 980 mbs. simultaneously in the Atlantic) and rate of development within the period 15th May to 15th June.

A reluctance to forecast movements of systems across the Atlantic at an average speed of 40 mph. or more in June therefore hardly requires justification.

2. The operational forecasts and the Weather in the Channel area from evening 4th June to evening 6th June

The assault was originally planned for the morning of the 5th, and the decision to proceed had to be taken on the evening of the 3rd, with a possibility of last-minute cancellation early on the 4th. Until early on the 3rd, it had seemed that a light or moderate West to WNW wind was reasonably assured, the difficulty being to predict amounts of low cloud.

The proximity of the ridge line made it rather doubtful whether the subtropical air in L4 (see Fig 1 - 6) would reach the Channel area with its consequence of very low cloud. The fact that falling pressure in West Ireland continued after the arrival of the main warm front indicated that conditions were liable to be much more disturbed, but a firm forecast as opposed to a statement of possibilities could not be made.

The arrival of the cold front on the 4th set these doubts at rest, and on its passage through the Channel area on the night of the 4th-5th it gave rise to Force 5 winds, with rain and much cloud at 1000 feet or below. These cloud conditions were not clear of the assault area until after 0600 on the 5th.

Hence, although the cold front did not figure in the forecasts issued on the 3rd, the cautious attitude necessitated by the continued pressure falls were fully justified in the event.

The difficulty of producing a detailed 36 hour forecast in disturbed conditions is well brought out by the fact that the cold front was far beyond the range of the routine meteorological reconnaissance flights (to about 25°N) made on the 3rd, and would have been beyond the range of a special flight timed to report at the last possible moment if such a report had been made available.

During the 4th, the situation clarified somewhat. It became evident that rapid eastward movement of centres had been broken by the deepening of L6 and the main problem became the determination of the speed of eastward movement of the fronts of L6 and the nature of the wedge between L5 and L6. Advice was needed on the evening of the 4th, with a view to assault early on the 6th, and the

synoptic picture on which this advice was based was a flat wedge moving east, with the warm front of L6 approaching the West Channel on the morning of the 6th. This would mean light to moderate westerly winds, with little cloud for the immediate assault, followed by a great deterioration to generally cloud conditions after midday on the 6th. In the event the centre L5 began a southeasterly movement on the 5th, whilst continuing to fill. A northwesterly gradient was maintained over the Channel areas, but did not reach its maximum until after the actual assault. There can be little doubt that there were Force 5 winds for a time on the beaches on the afternoon of the 6th, but not during the actual assault. This development held back the surface warm front, and the very damp air did not penetrate the Channel. Nevertheless, the warm air aloft played a part in conjunction with a series of upper level troughs in the maintenance of a thin but persistent layer of cloud at low medium levels, which greatly reduced the diurnal variation of the lower convective cloud. This diurnal variation was, however, sufficient to produce large local clearances by dawn on the 6th, and again on the afternoon of that day.

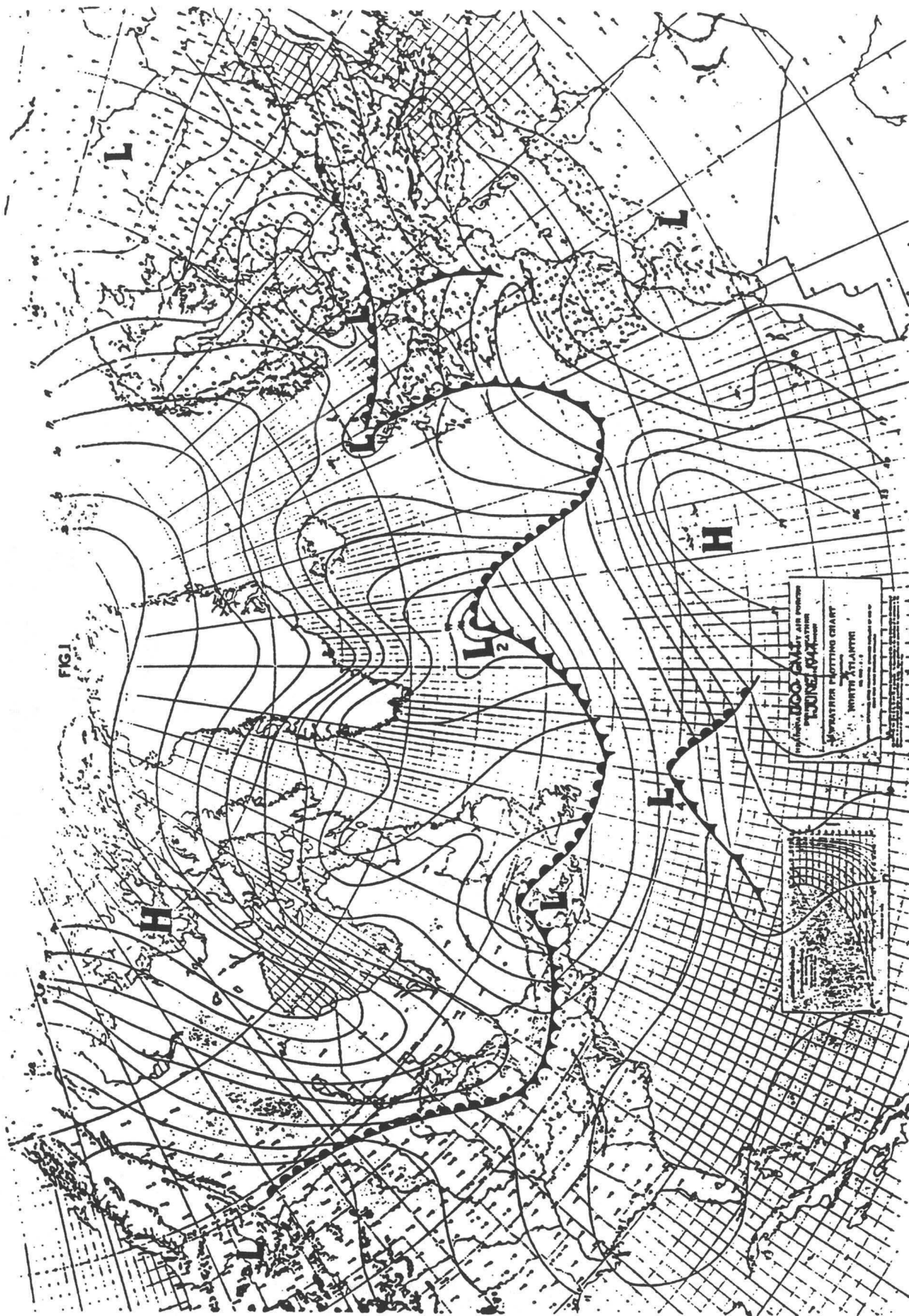
The southeastward movement of the centre was not forecast on the 4th, though it had been suggested by Widewing on the evening of the 3rd when the situation was less clear. The movement of the centres of rapidly filling occluded depressions, particularly when the history was as complicated as that of L5, is not a matter on which any firm opinion can be expressed. It is perhaps surprising that this movement was not mentioned as a possibility, but it could only have been put forward as the worst possible movement from the point of view of Channel weather. On the morning of the 4th it was a much more obvious possibility. This is yet another illustration of the difficulty of forecasting details over a period of about 40 hours in disturbed conditions.

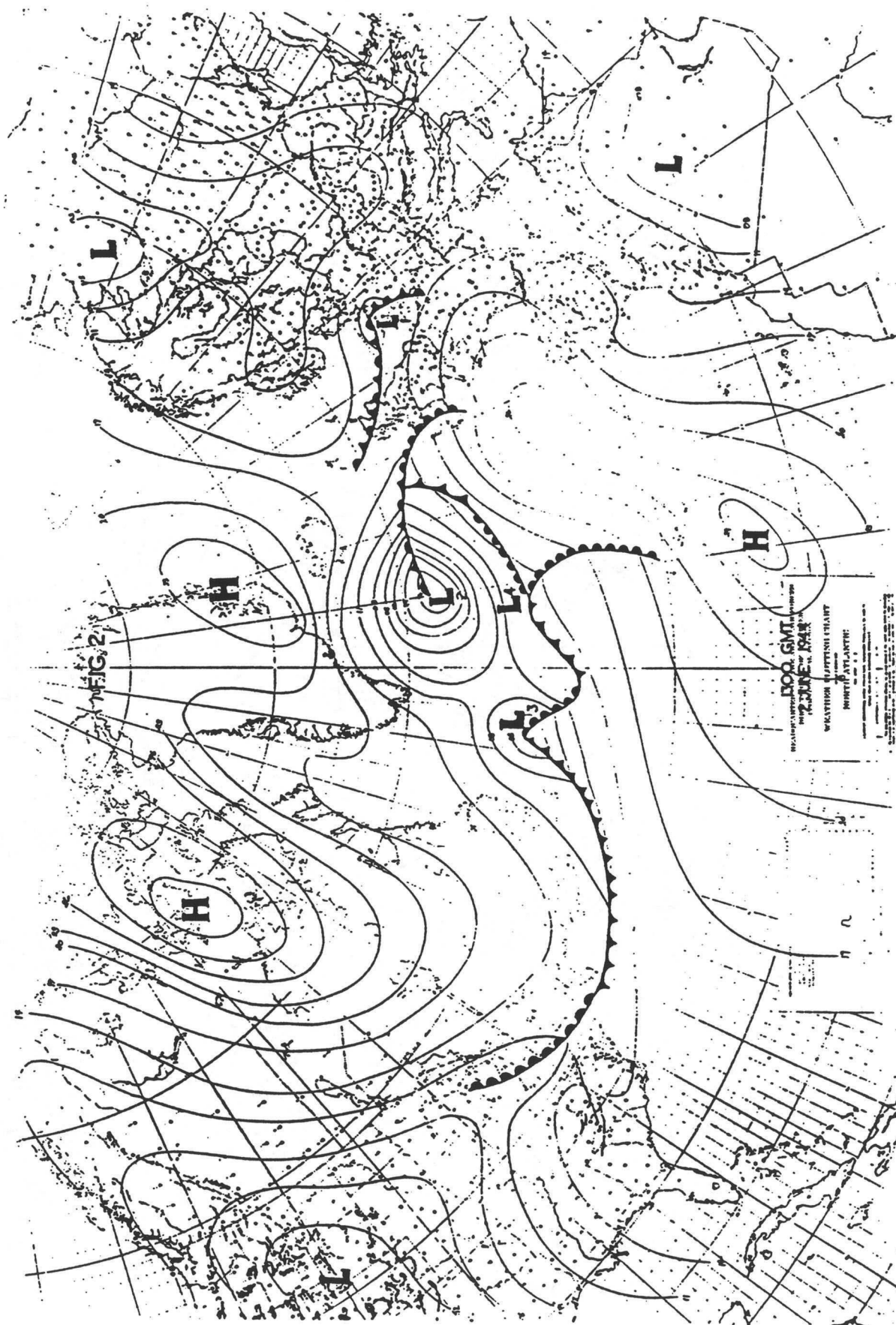
3. Long Range Forecasting Techniques

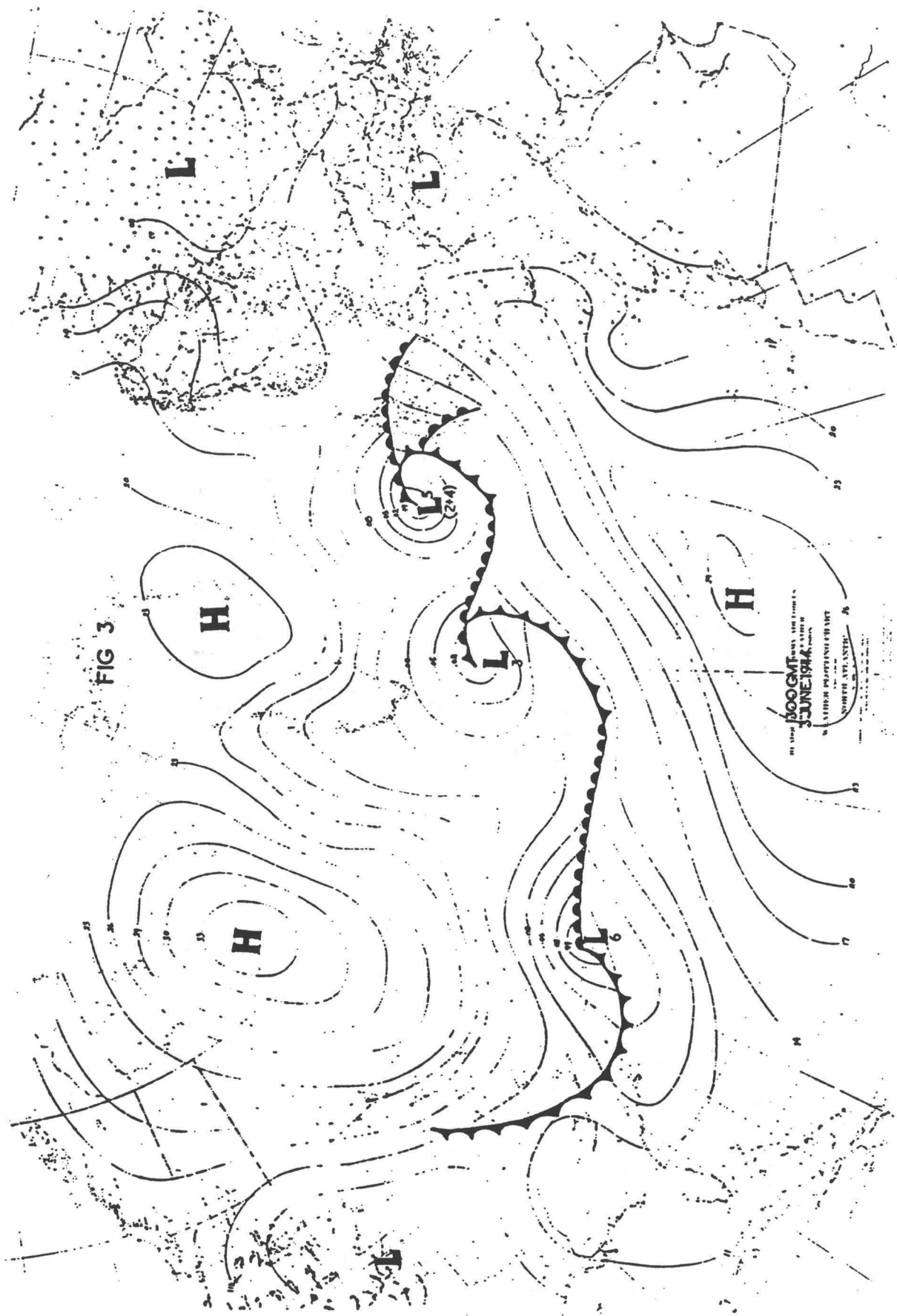
Reference is made elsewhere (see e.g. Section IX), to the assistance given by the various long range forecasting methods used by the Centrals; here it can only be remarked that it is doubtful whether the views of any of the Centrals were greatly influenced during the critical period by the semi-statistical methods mainly employed. They may perhaps have been useful as confirmation of views arrived at by more normal synoptic methods and may therefore have had an appreciable effect on the confidence with which those views were put forward.

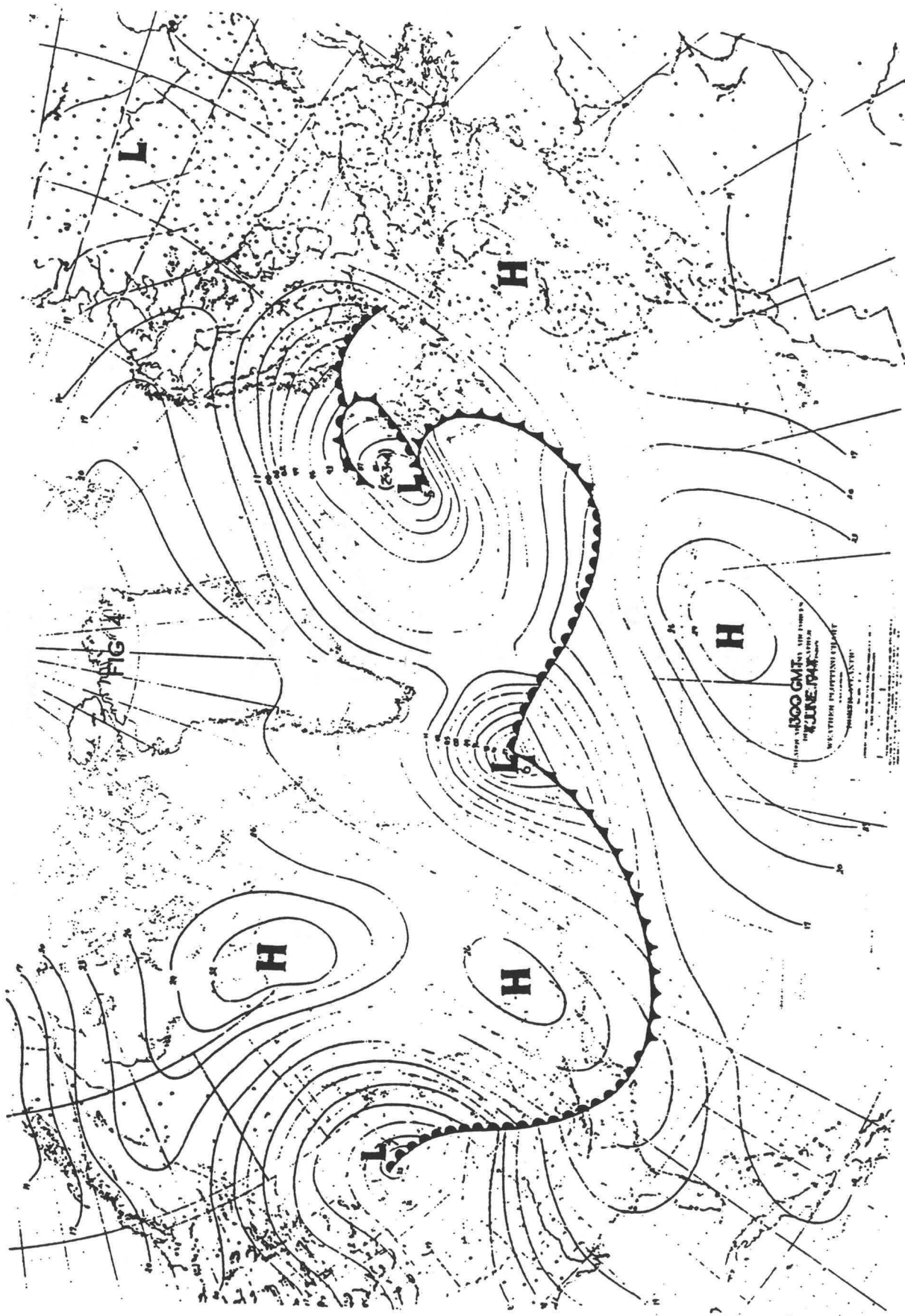
4. Observational reports

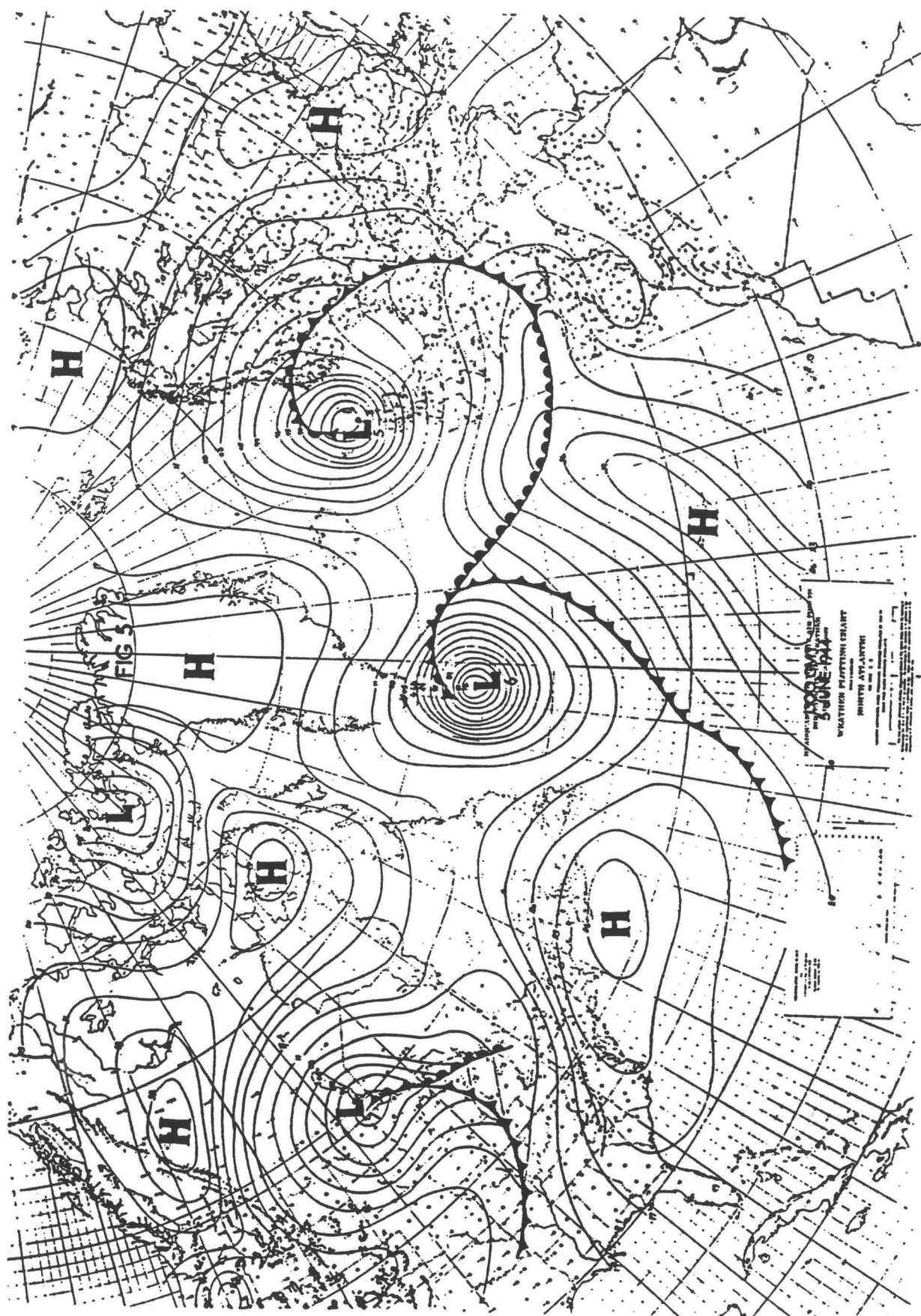
See paragraph 2 of Appendix A.











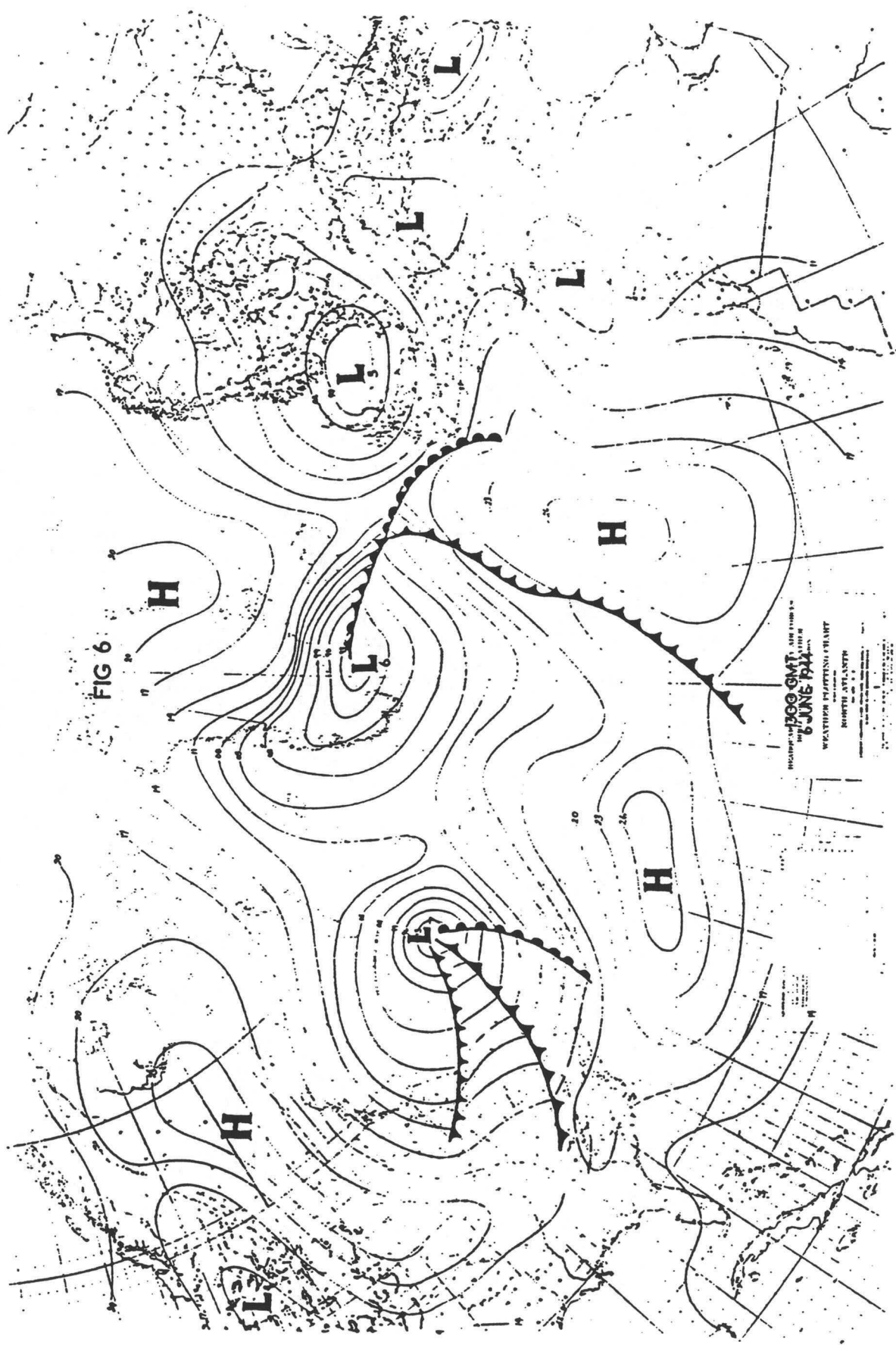


FIG 6

1000 GMT, 6 JUNE 1964
WEATHER PLATTEN (PART)
NORTH ATLANTIC

