ATMOSPHERE

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THE UPPER ATMOSPHERE AND METEOROLOGY TODAY – A REVIEW*

By A. D. Christie

The upper atmosphere may be defined as that part above a specific level; the choice of level has depended on whether the investigator's concern was magnetohydro-dynamics, aeronomy, radiative effects or dynamic processes. The other sessions at this First Annual Congress of the Canadian Meteorological Society have been generally limited to the troposphere, so in this session we shall use a meteorologist's definition of the upper atmosphere as incorporating everything between the tropopause and the lower thermosphere.

For short time periods when mass or energy exchange between different atmospheric regions is negligible, it has been possible to model the dynamic processes in a region independent of its bounding strata. As the length of the prediction time is extended it has become increasingly necessary to treat the atmospheric fluid envelope as a whole. This is illustrated by the work of Smagorinsky (1965), which shows that for prediction even at tropospheric levels for periods in excess of 4 days it is necessary to include information up to above 30 km in the model. Further, as meteorologists, our interests must not stop short with a knowledge of 'weather', though this clearly is a major economic justification behind our work. We must try to understand the dynamics of the circulation of the atmosphere as a whole, and the relative importance of different scales of motion, and their energetics, throughout the atmosphere, particularly as regards effects relevant to aerospace vehicle operations. Moreover, though the upper layers may have negligible effect on the lower layers the converse is plainly untrue.

I shall briefly describe the atmospheric structure in terms of gross thermal structure and indicate the physical and dynamical process of prime importance at various levels, and how these have been

*Survey paper presented as session theme at this 1st Annual Congress of the Canadian Meteorological Society, Ottawa, May, 1967.

investigated. This information is intended to provide a general background for the papers to follow and should give us a framework in which to develop an integrated programme of upper atmosphere study.

In figure 1, we see information from significant levels of the 1962 U.S. Standard Atmosphere. The temperature, plotted on a linear scale, shows the tropopause at 11 km, the familiar warm stratopause near 50 km, and the cold mesopause near 80 km. The concept of the tropopause as a continuous impermeable surface is long dead but many problems related to its unique specification, and its formation and maintenance remain. This morning Mr. Creswick will discuss objective computer-oriented methods of specifying the tropopause, the lower boundary of our region of interest.

A constant mean molecular weight of 28.966 is used up to 90 km, the region, sometimes termed the homosphere, and departures from this value as a result of photochemical effects and diffusive separation are not significant below 120 km. We can see from the pressure plot on a logarithmic scale on the right of the figure that less than .1% of the atmospheric mass is above 50 km and consequently that the energy there must be an extremely small part of the net atmospheric energy budget. In addition, the plot of collision frequencies shows that measurement techniques useful in the denser lower atmosphere would have excessive lag and poor resolution there, necessitating development of new measurement methods. The concept of local thermal equilibrium at these levels is inappropriate above the level of vibrational relaxation, the level at which the time required for the establishment of a Boltzman distribution of particles in various vibrationally excited states by collisions becomes greater than the average radiative lifetime of the excited levels. This has been roughly estimated as near 70 km for the relevant radiative substances in the mesosphere by Curtis & Goody (1956), and creates problems in theoretical studies of the mesospheric-thermospheric energy budget.

I already stated that the mean molecular mass is invariant up to the lower thermosphere - as diffusive separation, (detected by measuring ratio by mass of one of the inert trace gases to the major molecular nitrogen component) begins only above the turbopause i.e. the level at which eddy diffusion ceases and molecular diffusion dominates. Photochemical effects however, which affect certain trace constituents such as oxygen (O, O_2, O_3, neutral, ionized, excited) and oxides of nitrogen and hydrogen, are important in various upper atmosphere strata. The photochemically-produced trace constituents are important from two points of view, from the contribution their reactions have in the radiation budget of the upper atmosphere and as possible tracers of the atmospheric motions occurring in the regions, when, or perhaps better, if the strength of the sources and sinks can be accurately estimated theoretically. The value of ozone, in the special case where it is effectively conservative below 30 km, has been widely demonstrated in this respect.

These photochemical effects can not be neglected in studies of upper atmosphere dynamics as they effect the distribution of heat sources and sinks through the concentration of absorbing and emitting constituents. Analyses of airglow spectra, laboratory studies such as are carried on at York University, and the measurements of vertical profiles of ultraviolet flux of Brewer & Wilson (1965), all contribute to a better specification of these reactions. These can then be used in numerical models of the general circulation of the region such as those of (Leovy, 1964) or that of Byron-Scott, the results of which will be presented later by Prof. Boville.

Near the mesopause and above, heating also results from energy influx from solar corpuscular radiation directly by collisions with these extremely energetic particles, and indirectly by chemical transfer reaction with nascent oxygen whose number density is increased by dissociation of molecular oxygen by the auroral particles as studied by Maeda (1963). These effects will be discussed later by Prof. Gregory.

The change in emphasis from aerodynamic to physical processes with increase in altitude has been reflected in the parallel development of studies of the upper atmosphere by the meteorologist on the one hand and the aeronomer and ionospheric physicist on the other. A few comments on this twin development seem appropriate.

Meteorologists are aware of the upward extension of balloon ceilings from mid-troposphere in the forties to 30-40 km levels by the early sixties and the rapid and interesting advances in lower stratospheric analysis. The early subjective analysis of weekly mean values was rapidly superceded by daily analyses and the development of object methods by Teweles group in Washington D.C. prior to and during the I.Q.S.Y. (Finger, F.G. et al, 1965; E.S.S.A., 1966). This work and the current analysis programme of maps to 10 mb have permitted studies of the stratosphere to proceed rapidly from the early crude analyses of time series and simple speculative models of the large scale dynamic processes, to somewhat sophistacted analyses of the energy budget from observational data, and to numerical simulation of the circulation.

Analysts for these levels have had to contend with problems of sparsity of data, variable radiation corrections, and the increasing power in the tidal components of the observational spectra of winds and temperature, which must be filtered in analyses of planetary waves.

Ozone in the atmosphere has also been measured over extensive areas using ozone spectrophotometers, and in recent years various types of environmental sampling sensors. The information has been used to study transfer processes in the lower and middle stratosphere where the ozone may be considered conservative for periods up to a month. The source, where the ozone comes quickly into photochemical equilibrium, is at and above mid-stratosphere. The ozone profile, which is then related to the planetary wave systems, exerts a feedback in the dynamics of the system through the absorption of solar U.V. I have specifically mentioned the relationship with planetary waves simply because no greater resolution is practicable with the present sparse station network, which is notably inadequate in the polar night. It is to be hoped that over the next few years we can fill this observational deficit with information from sondes, and with stellar spectrophotometers such as will be described by Dr. Wardle today. The importance of introducing the ozone heating effect into a numerical model of the stratospheric circulation will be illustrated by the paper presented by Prof. Boville.

The common feature of the meteorological approach to the upper atmosphere has been the bias to study planetary wave phenomena inductively, whereas the sparsity of data at higher levels has led to a more deductive approach where infrequent sporadic observations have been used as verification of theoretical models.

Examples of these latter types of model were developed by physicists concerned with interpreting variations in the earth's magnetic field, in the solar spectrum and that of the airglow and aurora, in ion density fluctuations, meteor trails drift and noctilucent cloud, all associated with events in the remote regions above 70 km. Perhaps the arbitrary gap imposed by observational techniques accounts for the limited exchange of information and ideas between these physicists and meteorologists until quite recently, but the arbitrary nature of the boundary between the various disciplines has become more embarrasingly clear with the advent and widespread use of rocket sounding of the region from 35 km to ionospheric levels.

Some of the remote sampling methods are worthy of specific mention.

Noctilucent clouds, occurring near 80 km between latitudes 45° and 75°, are observed sporadically during the months of March to

October when they are illuminated by scattered sunlight and when the lower atmosphere is within the earth's shadow. The drift of these cloud masses, which is difficult to estimate, gives information on the summer prevailing winds, but can give little information on diurnal and seasonal fluctuations when observed visually or photographically as a result of their selective observational period. They may be used to study gravity wave phenomena however and by study of the wave propagation in the small 'wave' structure ($\sim$ 10 km) information may be obtained concerning the flow at the cloud level. The Canadian Meteorological Branch has been participating in a programme of visual observation of noctilucent cloud, and the results from 30 stations during the I.Q.S.Y., and about 70 last year have been studied to see if any planetary wave phenomena were apparent at these levels.

Further information on the winds in the mesosphere and lower thermosphere have been obtained using a phase shift techniques in radio echoes from the ionized trails left by meteors vaporising in the region between 70 and 120 km. This method has the obvious advantage of permitting continuous observation and hence study of seasonal and tidal oscillations. The results from Jodrell Bank (53°N) (Greenhow, 1954; Greenhow and Neufeld, 1960, 1961), Adelaide (35°S) (Elford, 1959), and Mawson, Antarctica (68°S) have contributed a large part of the knowledge on upper atmosphere tidal fluctuations but much remains to be learned. Three radars, suitable for such studies, are operated in North America and a fourth is under construction at White Sands, N.M., while, there are 7 in the U.S.S.R. At present I am unaware of any studies of planetary waves using these systems.

Many observations on the airglow have been made but their value as tracers is limited to studies of a climatological nature at present, as a result of difficulties in measurement, in calibration of dayglow and nightglow and in distinguishing between the purely photochemical effects and those of dynamic origin. Attempts have been made to study the transfer processes in the mesosphere using information on the emmissions of sodium, nascent oxygen, and hydroxyl by Hunten, Gadsden, Godson, Newell and others but the studies are still in an embrionic stage. It may become possible to study drift in airglow irregularities using three vertically alighned photometers, and obtaining information on the planetary wave component by removing the tidal component.

A further means of remote sounding of the lower thermosphere is by study of ionospheric irregularities. In figure 1 we observe that the ion concentration increases from negligible amounts near 70 km through the D and E layers. The height at which reflection of a radio signal takes place is a function of the frequency of the signal, the number density of electrons, and the collision frequency. For any given frequency of radio-probe, fluctuations in electron density resulting from an imposed wave form will result in changes in the recorded reflected signal at a receiving station. By spectrum analysis of the records obtained at three receivers forming a triangle on the ground, the apparent movement of the various Fourier components in the records may be studied. One such experimental layout has been operated successfully by Gossard (1967) in the southern U.S. using very low frequencies to study movement near 90 km. Another method using scattering rather than reflection, which is capable of giving drift at more than one level, in fact at any electron density discontinuity, was built and operated by Gregory in New Zealand, and another is under construction at Saskatoon.

Having exhausted the remote probe techniques available we can see that post World War 11 Developments in Rocketry were necessary before we could fill in the observational gap between 35 km and the mesopause.

Much of the early information from rocket sounding was obtained using large costly rockets of wartime development, and sampling was sporadic and oriented towards special projects in ionospheric regions. The major advances from a meteorological viewpoint came with the development of smaller cheaper rockets and economical sensor packages. Various agencies in the U.S. coordinated their activities through the Meteorological Working Group of the Inter-Range Instrumentation Group and developed the Meteorological Rocket Network (Joint Scientific Advisory Group, 1961). Operations began in 1959 with two stations, Point Mugu, California, and Ft. Churchill, Canada. During the first year five more stations were added as illustrated in figure 2. Canadian participation in this venture has been noteworthy so far by its absence. It is to be hoped that with the challenges of polar stratospheric meteorology staring us in the face, it will not be too long before Meteorological Branch plans for meteorological rocket stations in Canada become a reality.

The frequency of successful firing with Loki and Arcas vehicles to about 60 km is still highly variable at different stations, but the synchronous observations made during the I.Q.S.Y. were analysed as height contours at 5, 2 and 0.4 mb levels by the Upper Atmosphere Analysis laboratory of E.S.S.A. (Finger et al, 1966).

The temperature sensors used in these probes are of the thermistor type, but if we wish to study the thermal structure at higher levels more sophisticated techniques must be resorted to as a result of the low collision frequencies encountered there.

The higher cost of the rockets and launch facilities necessary to probe the upper mesosphere and lower thermosphere has resulted in sampling being even more sporadic than at the stratospause level. Information on the density and thermal structure at these levels has been deduced from methods using pitot tube, tracking a falling sphere, surface acoustic measurements of explosing grenades ejected from rockets at successively higher levels, and shock wave angle measurements, as reviewed by Craig (1965).

Fluctuations in the upper atmosphere.

We commented briefly earlier that oscillations of periods ranging from many months to minutes were present in the upper atmosphere, and their relative contributions to the energy spectrum are functions of both location and time. The following remarks on the distribution of these scales must be superficial but seem advisable.

First in figure 3, we can see the familiar mean meridional cross sections of winds and temperature. The sections are prepared from information from Batten (1961), Kantor & Cole (1964 a, b, 1966) modified in low latitudes for additional rocket data, analysed by Reed (1966) and Kantor, Cole & Nee (1965). (The most comprehensive analysis of such data will soon be available in the form of Supplemental Atmospheres.) They are in approximate geostrophic balance. An interesting feature of the sections still to be explained is the discrete existence of the mid-tropical, mid-stratospheric easterly jet stream which studies of rocket wind data by Kantor & Cole 1964, and Reed (1966) suggest to be real. (This feature was deduced by Murgatroyd (1957) from the thermal wind relationship and an adopted temperature distribution but he concluded it might well be fictitious.) It remains to be explained why this jet should persist independently of the main body of the summer mesospheric easterlies.

In passing we will also draw attention to the major differences between the measured temperature distribution and what would result from radiative processes in figure 4 as computed by Leovy (1964). No figure has been prepared, but comparison indicates the actual temperatures to be from 50-70 degrees below the computed values at the mid to high latitude mesopause in summer and uniformly too warm from tropause to mesopause in the polar night.

Clearly, dynamical transport of heat and absorbers can not be neglected in the mesosphere any more than in the troposphere, and the heating by auroral particles and small scale periodic waves propagating energy into the upper mesosphere and lower thermosphere must also be considered.

In figure 5 we see the amplitudes of some climatological variations of the zonal wind in metres per second. The annual cycle increases rapidly in amplitude outwards from the equator and rises in level from about 40 km in the tropics to 65 km in the subtropics and higher latitudes. The amplitude of both the quasi-biennial (25 months) and semi-annual cycles, as derived from balloon and rocket profiles in low latitudes are greatest in the tropics but drop off rapidly to the north.

For the moment the limited rocket information for high latitudes has not shown significant power in these cycles in the stratosphere and mesosphere, though analysis of meteor trail winds from Jodrell Bank (53°N) (Greenhow and Neufeld, 1961) and Adelaide (35°S) Elford, 1959) for 90 km suggest a semi-annual component in the zonal wind field which is much more marked at the station further from the equator.

Planetary waves of wave-number 4-6 are in general more pronounced in middle and high latitudes in the lower and middle stratosphere, where the forced waves systems resulting from energy propagated in from the troposphere, is generally rapidly damped as discussed by Charney & Drazin (1961). In winter the stratospheric and mesospheric fluctuations, predominantly of wave numbers 1 and 2, arise in situ from energy conversion in the polar night vortex. These waves are illustrated in the stratosphere and lower mesosphere by figures 6-9.* Figure 6 shows a typical 10 mb (30 km) hemispheric analysis as prepared daily by E.S.S.A.; many wave numbers are clearly present. Figures 7 and 8 illustrate selected cases of a special series of analyses at 5, 2 and 0.4 mbs (35, 40 and 53 km) which were done at weekly intervals during the I.Q.S.Y. using Meteorological Rocket Sonde Network data, by the Upper Atmosphere Analysis Laboratory of E.S.S.A. The low wave number planetary waves are marked throughout both winter seasons. Obviously the spatial scale of features to be delineated is limited by the separation of stations and the grouping of observations for analysis, but the

*(We are indebted to the Upper Atmosphere Analysis Laboratory of the Environmental Science Services Administration, for permission to publish figures 6-9 above.)

evidence for the longer waves in winter up to the lower mesosphere is irrefutable. Figure 9 shows the zonally-symmetric summer circulation with no evidence of planetary waves but the E.S.S.A. analysts have commented that, even after removal of the tidal wind components which are significant in the lower mesosphere, the wind vectors frequently depart from zonal flow by 10 - 30 degrees, and note that these variation could be attributable to transient planetary waves. Clearly, the addition of some Canadian rocketsonde stations could provide a useful improvement in resolution.

The number and frequancy of rocket observations to higher levels precludes their use in investigating the existence of planetary waves into the lower thermosphere, though their existence has been speculated upon.

Bossalosco and Elena (1963) noted similarities in winter time series of radio absorption in the D layer and pressure changes at 10 mb. Gregory (1965), Benyon and Jones (1965) and Lauter and Sprenger (1967), have related D layer changes with stratospheric temperatures. Greenhow and Nuefeld (1961) have noted the existence of wind changes with irregular periods of a few days which could be interpreted as planetary waves. Hunten and Godson (1967) have noted an apparently significant correlation in winter between sodium abundance and lower stratospheric temperatures over periods of several days, and Grishin (1954) has claimed to note a relationship between noctilucent cloud occurrences and tropospheric anticyclones. The absence of corroborative evidence for the last relationship in more recent studies in the U.S.S.R. (Kurilova, 1962) and Canada (Christie, 1967) in no way negates the other results as the figures of analyses at 53 km have already shown the summer circulation when noctilucent clouds occur to be much less meridionally disturbed than the winter season.

Wulf (1965) has shown the existence of fluctuations on the horizontal component of the magnetic field during the I.Q.S.Y. but the method of analysis suggests these to be of tidal rather than synoptic type.

Clearly, a knowledge of the stratospheric and mesospheric circulations can contribute to the interpretation of physical processes taking place in the mesosphere and lower thermosphere, and are very important in boost-glide space vehicle re-entry (Sissenwine, 1967). Equally important may be the presence of noctilucent cloud, or the dust layers frequently found at the mesopause, even in the absence of NLC, by the laser studies of Fiocco and Colombo (1964) and Fiocco and Grams (1966).

Three other classes of waves of shorter period exist in the upper atmosphere: tidal oscillations, internal gravity waves and acoustic waves.

Tidal oscillations have periods which are equal to or submultiples of the solar or lunar day. Until relatively recently information on atmospheric tides came from studies of their integral effect on pressure, for example at the earth's surface, or from inferences on the tidal effects in the ionosphere from variations in the magnetic field at ground level. The notation adopted to specify tidal components is a capital letter S or L to designate solar or lunar tides respectively, followed by an intergral subscript, ℓ , such that the period of the oscillation is $1/\ell$ of the daily period, and superscript, m , where m is zero for a stationary oscillation or a positive integer for a westward travelling oscillation.

Tidal oscillations increase rapidly in amplitude with height as has been speculated since Stewart (1878) first proposed the ionosphere dynamo theory to interpret daily variations of geomagnetic parameters. In recent years these periodic oscillations, particularly the first three wave numbers of the solar period the diurnal S_1^1, semi-diurnal S_2^2, the teriurnal S_3^3, have been studied empirically using data from chemiluminous cloud observations (Hines, 1966, Kochanski, 1966, Murphy et al 1966), radio sounding of meteor trails (Greenhow & Nuefeld, 1960, 1961, Elford, 1959), stratospheric balloon borne sensors (Harris, Finger and Teweles, 1962), and rockets (Lenhard, 1963, Reed, McKenzie & Vyverberg, 1966, Miers, 1965, Beyers & Miers, 1965 and Thiele, 1966).

Empirically the picture of amplitude that emerges is roughly as follows:

The diurnal and semi-diurnal solar tides appear to be the ones of major significance. The amplitudes of the zonal wind components appear to be about the same order of magnitude up to the mesosphere, increasing from about 0.2 m. sec^{-1} at the tropopause, to 4 m. sec^{-1} at mid stratosphere and rapidly to 20-25 m. sec^{-1} near the mesopause. Insufficient data have been accumulated to indicate the distributions of amplitudes and phases with location, and such information is required to verify the models proposed by Webb (1966) Reed et al (1966).

Following the epic review of tides by Siebert (1961) considerable advances in tidal theory have recently been made. (Green, 1965; Lindzen, 1966, 1967, Harris et al, 1966.) Resonance theories, thought necessary to explain the greater magnitude of the S_2^2 (p_o) amplitude compared to the S_1^1 (p_o), have been found unnecessary when the effect of introducing a heating function which incorporated the stratospheric ozone U.V. absorption was used by Butler & Small (1963). Mr. Nunn will discuss these problems later today.

Hines (1960, 1963) gave a plausible interpretation of apparent turbulence in the ionosphere in terms of internal gravity waves which propagate energy upwards from lower levels. These waves and the tidal oscillations discussed above share the property related to conservation of energy, of amplifying with height. They can contribute significantly to the heating of the thermosphere by viscous damping. The shorter waves which propagate energy closer to the vertical (Hines, 1960, Zhukova and Trubnikov, 1967) are damped most rapidly, which is consistent with the increasing scale of the dominant mode with height.

In recent years this type of wave structure has been studied using high resolution vertical profiles of horizontal wind obtained from photogrammetric observation of chemiluminous trails from rockets in the lower thermosphere and from radar tracking of Robin spheres in the height range 35-70 km (Lettan, B., 1966, Newell, 1966). Further information on the horizontal structure of these waves can be obtained for specific levels from radio-sounding of the ionosphere and from noctilucent cloud displays, but to date these results have not been available from the same location.

Measurements of phase lag with height, increase in wavelength of dominant mode with height, ratio of vertical horizontal wavelength, and velocity components are consistent with the crude models. Little is yet known about the source of these waves, and for the moment there is no way of evaluating zonal variations in intensity of internal gravity waves, a fact that may be important in estimating zonal asymmetries of winter thermospheric heating resulting from their viscous dissipation.

This gross sketch of the meteorologist's upper atmosphere will, I hope, serve to indicate the fragmentary nature of our current knowledge of the region. It reminds me of the definition of a camel as a horse designed by a committee. I suspect a committee who could communicate could at least produce a streamline dromedary. In this first year of the Canadian Meteorological Society the time is ripe for those of us with interest in the upper atmosphere to discuss how best we can transform our camel into a more elegant beast.

The theoretical problems are manifold, suggesting laboratory studies, instrument development and methematical modelling experiments which may be done better by Universities than by government agencies.

Costly observational programmes requiring regularity and consistency would appear to fit better under the aegis of the civil service.

This being so I will refrain comment on the former aspects, and discuss briefly proposals for empirical study of the atmosphere likely to contribute to our knowledge of the circulation.

First ozone. This morning's papers will demonstrate the importance of ozone heating in both general circulation and tidal oscillations, and the potential to measure it in currently information-poor regions, using the Brewer Bubbler sensor and the Stellar spectro-photometer. The Meteorological Branch could develop an ozone measuring network in the arctic which could contribute significantly to the Global Atmospheric Research Project by the time of completion.

In noctilucent cloud studies we already have an excellent surface network of visual observation stations which can provide further knowledge of climatological information on gross mesopause temperature structure and gravity wave distribution. We should make use of our mobile stereo-photography unit and those at Churchill Research and Cold Lake to study height changes and wave propagation in the clouds, particularly during special events such as the Suffield 500 ton trial in 1968 and the A.F.C.R.L. rocket sampling of particulate matter from the noctilucent cloud layer at Churchill in 1968.

The distribution of rocket sounding stations on the analyses shown earlier indicates the limited nature of Canadian effort in observational study of the upper stratosphere and lower mesosphere. Now is the time for more active Canadian participation and present meteorological rocketsonde program plans should be pushed vigorously.

Finally we have seen how a major problem in interpretation of upper atmospheric data arises from the spatial separation of sites where observations are taken, and the questionable consistency of the various methods used. What would obviously be extremely worthwhile would be the development of one or more versatile centers where many parallel studies and intercomparison of different techniques could be carried out. An essential feature of these centers would be permanent technical staff to ensure continuity of the observational records. A comprehensive program might include the following:

> <u>Stratosphere</u>: Balloon borne temperature and ozone sensors and appropriate ground equipment including ozone spectrophotometers; net flux radiometer sondes; lidar to study aerosol layers and their relation to

radiative flux and ozone photochemistry; meteorological rocket capability with precision radar to study fine resolution not possible with GMD equipment.

<u>Mesosphere and Lower Thermosphere</u>: Photometers to study airglow and investigate the relative contributions to variations in the emitted intensities from photochemical and dynamic effects; stereophotogrammetry of noctilucent clouds, and of chemilucent trails from high level rocket ascents; radio scattering methods to study drift and/or phase propagation of dynamic waves at levels of electron density discontinuity; a radar system to obtain reflection from meteor trails and determine the three dimensional wind such as that operated by Barnes of M.I.T., and being modified in the White Sands installation currently under construction.

Development of such establishments would be an ambitious and expensive undertaking, involving cooperation between Universities and government agencies. Perhaps the first decade following the inception of the Canadian Meteorological Society will show this ambition to be realised.

Figure 1. Vertical profiles of selected parameters (temperature, pressure scale height, pressure and collision frequency) from the 1962 U.S. standard atmosphere; and a schematic daytime profile of electron number density for mid-latitudes.

Figure 2. Stations in North America and its environs participating in the Meteorological Rocket Network.

Figure 3. Composite meridional, summer - winter cross-section of winds and temperatures between 20 and 85 km. Solid lines represent winds in metres per second, and dashed lines temperature in degrees absolute (from Kantor and Cole, 1965).

Figure 4. Meridional summer - winter cross-section of temperatures resulting from radiative processes (Leovy, 1964). Isopleths show temperatures in degrees absolute.

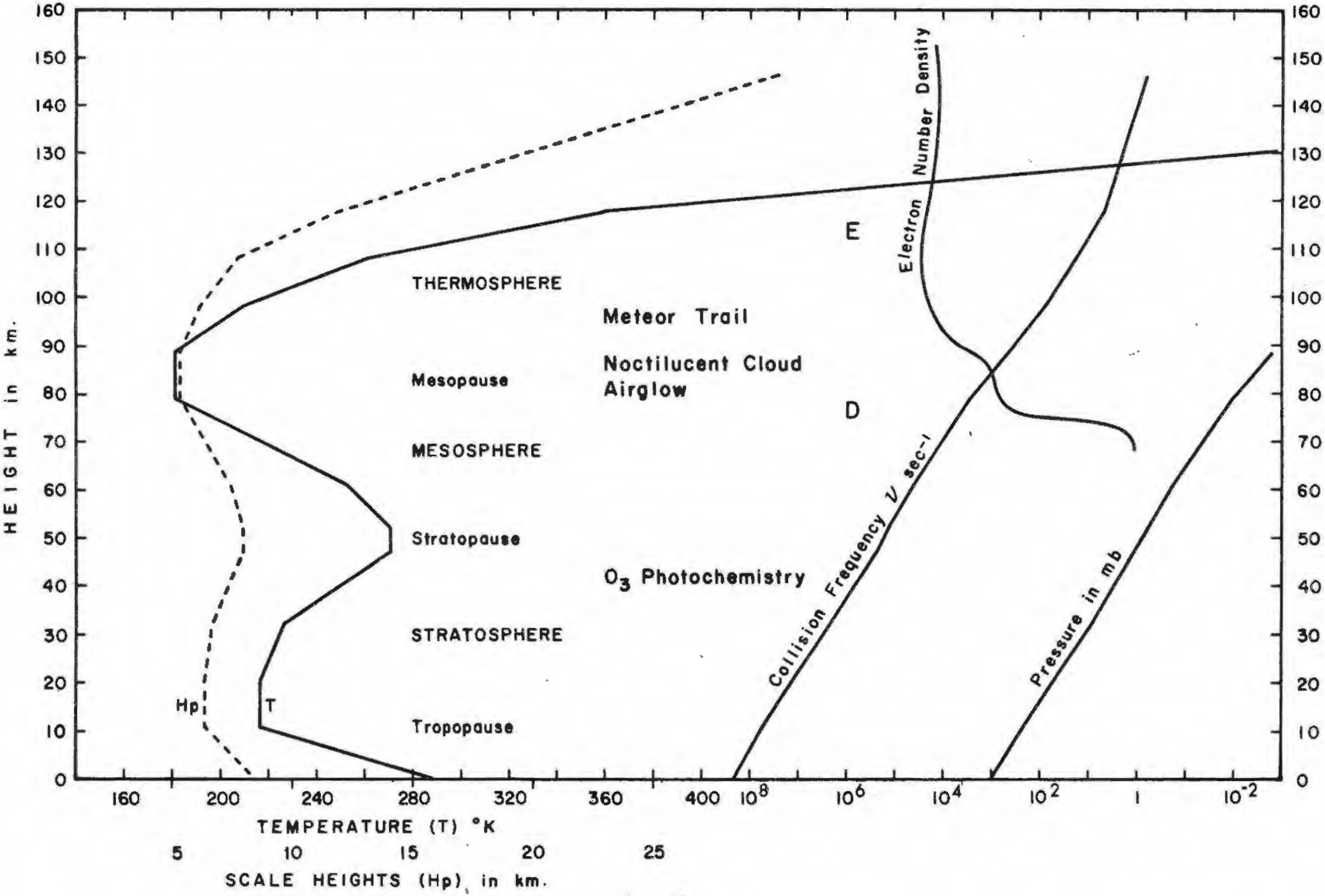
Figure 5. Amplitudes of various climatological periodic fluctuations in the zonal wind component between 20 and 80 km. The amplitudes of the annual, quasi-biennial and semi-annual variations are represented by the solid, dotted and dashed isopleths respectively. Units are in $m.s^{-1}$.

Figure 6. A typical winter-time 10 mb level analysis of height and temperature as produced by the objective methods of the Upper Atmosphere Analysis Laboratory of E.S.S.A. Solid lines represent contours and dashed lines isotherms.

Figure 7. Typical vertically consistent analyses of heights on 5-, 2- and 0.4 mb levels in winter, analysed from Meteorological Rocket Network information during the I.Q.S.Y. by the Atmospheric Analysis Laboratory of E.S.S.A.

Figure 8. A further series of 5-, 2- and 0.4 mb analyses similar to figure 7 for the succeeding winter, 1965.

Figure 9. A 0.4 mb analysis prepared from Meteorological Rocket Network information representative of the summer anticyclonic circulation.


HEIGHT in km.
THERMOSPHERE
Meteor Trail
Noctilucent Cloud
Airglow
Mesopause
MESOSPHERE
Stratopause
O_3 Photochemistry
STRATOSPHERE
Tropopause
Hp
T
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D
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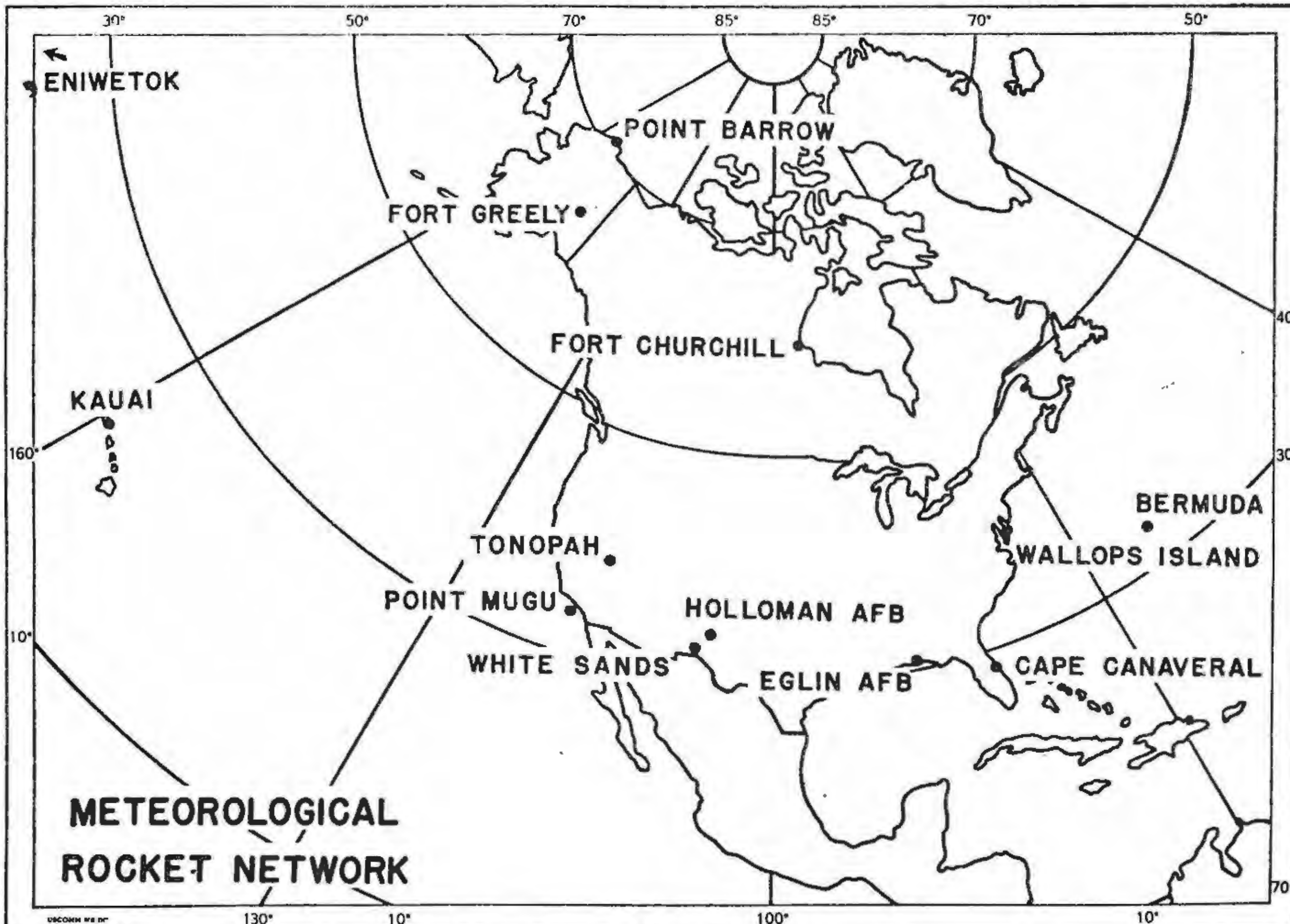
Collision Frequency ν sec^{-1}
Pressure in mb
TEMPERATURE (T) °K
SCALE HEIGHTS (Hp) in km.

Fig. 1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METEOROLOGICAL
ROCKET NETWORK
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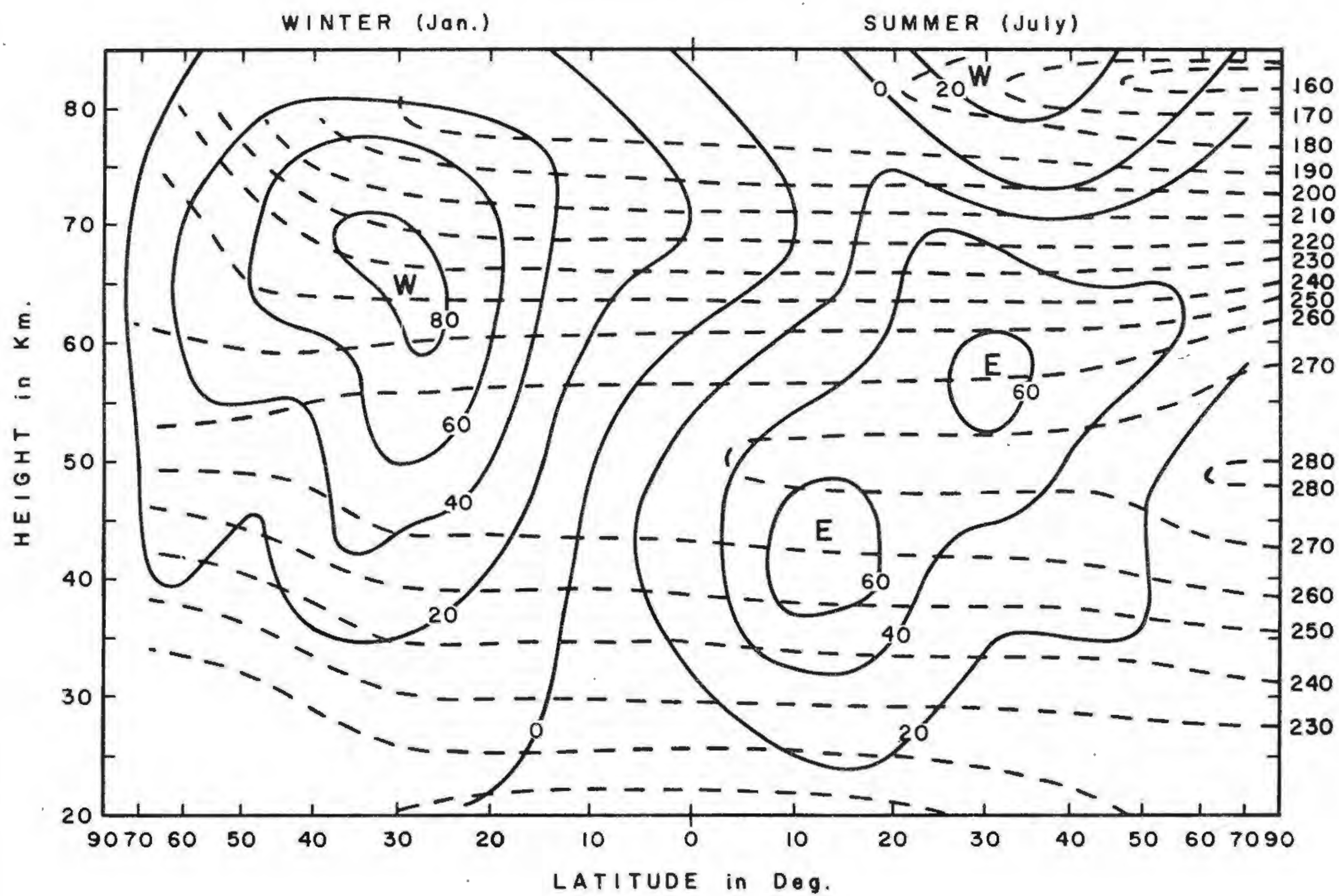
Fig. 2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SUMMER (July)
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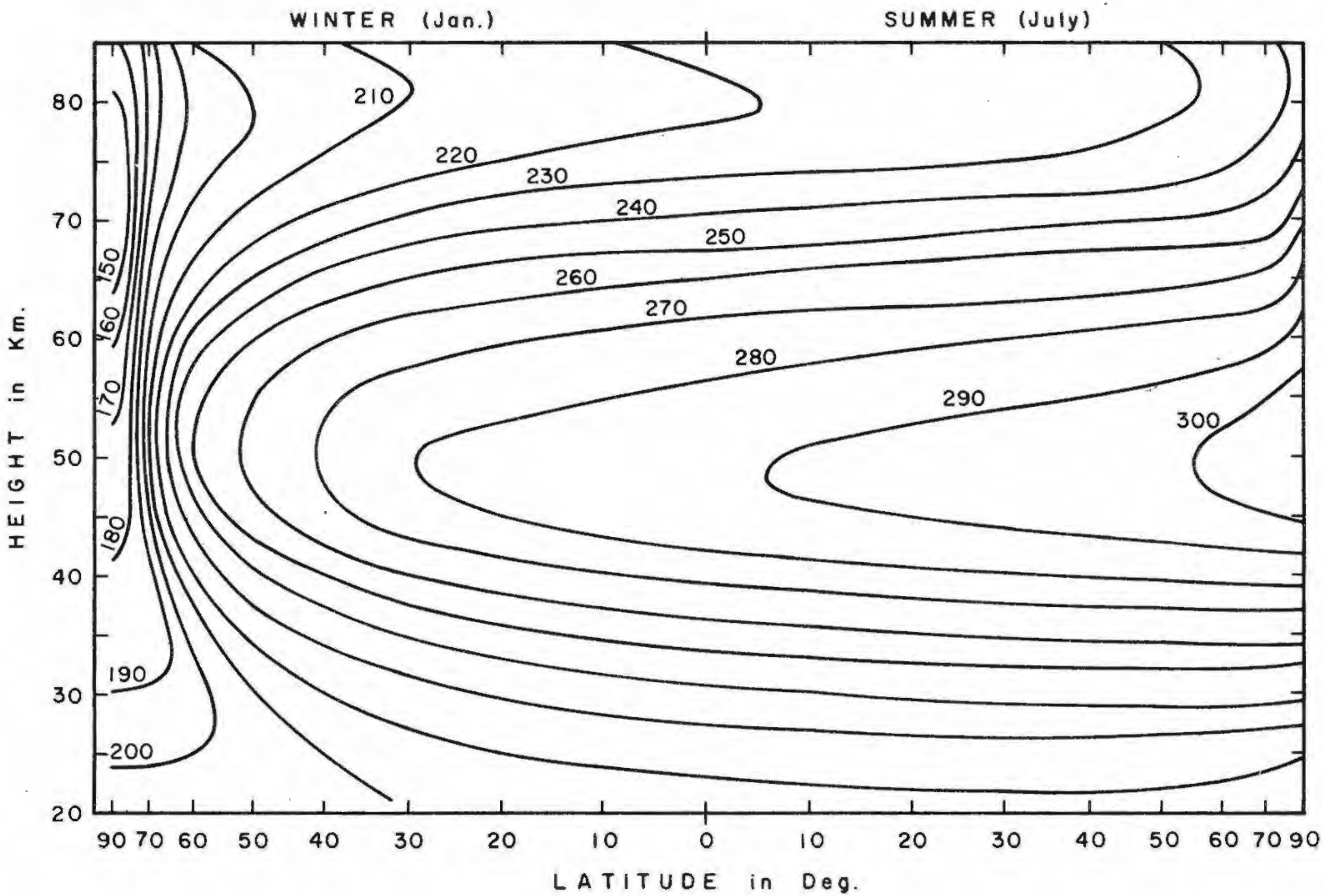
Fig. 3


WINTER (Jan.)
SUMMER (July)
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LATITUDE in Deg.
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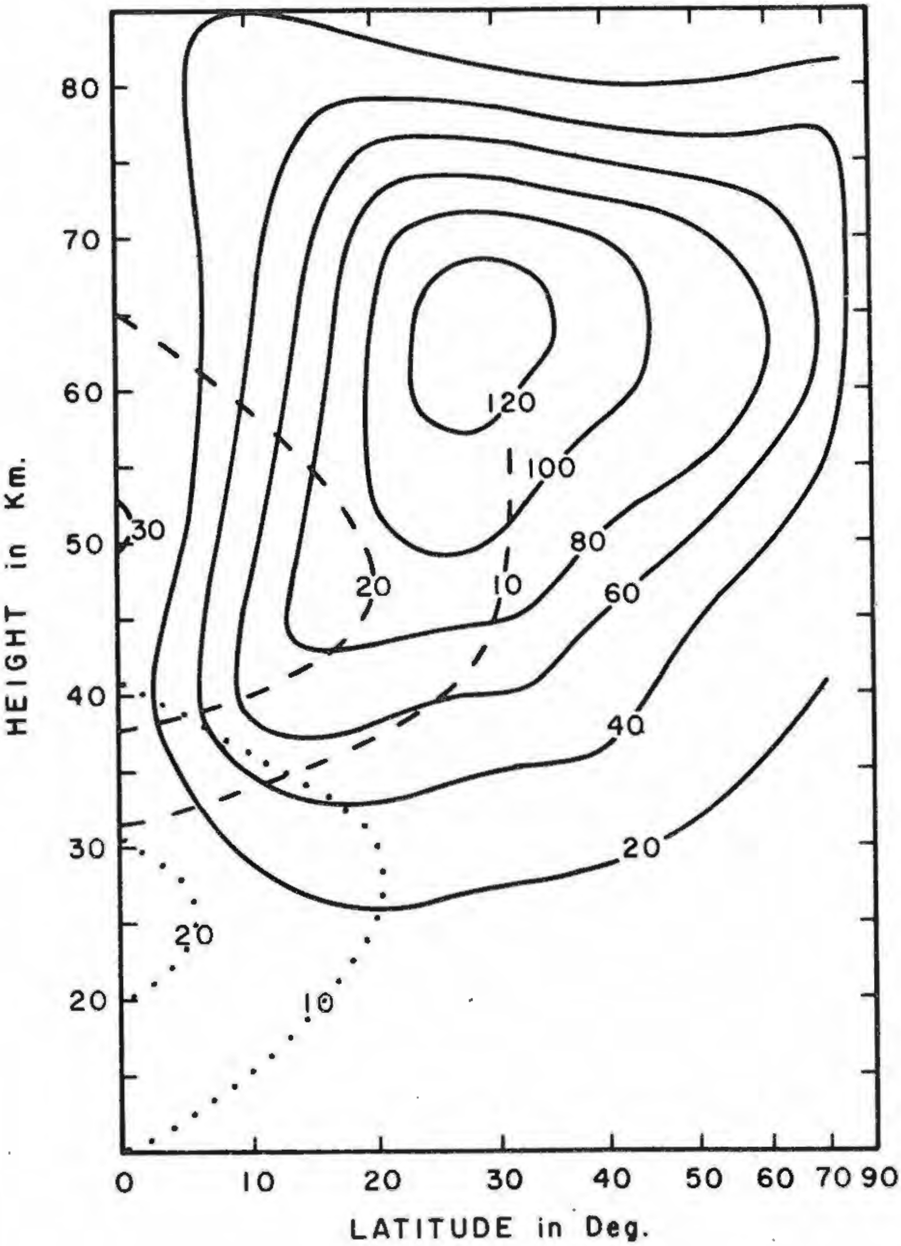
Fig. 4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30
20
HEIGHT in Km.
0
10
20
30
40
50
60
70
90
LATITUDE in Deg.
120
100
80
60
40
20
30
20
10
20
10

Fig. 5

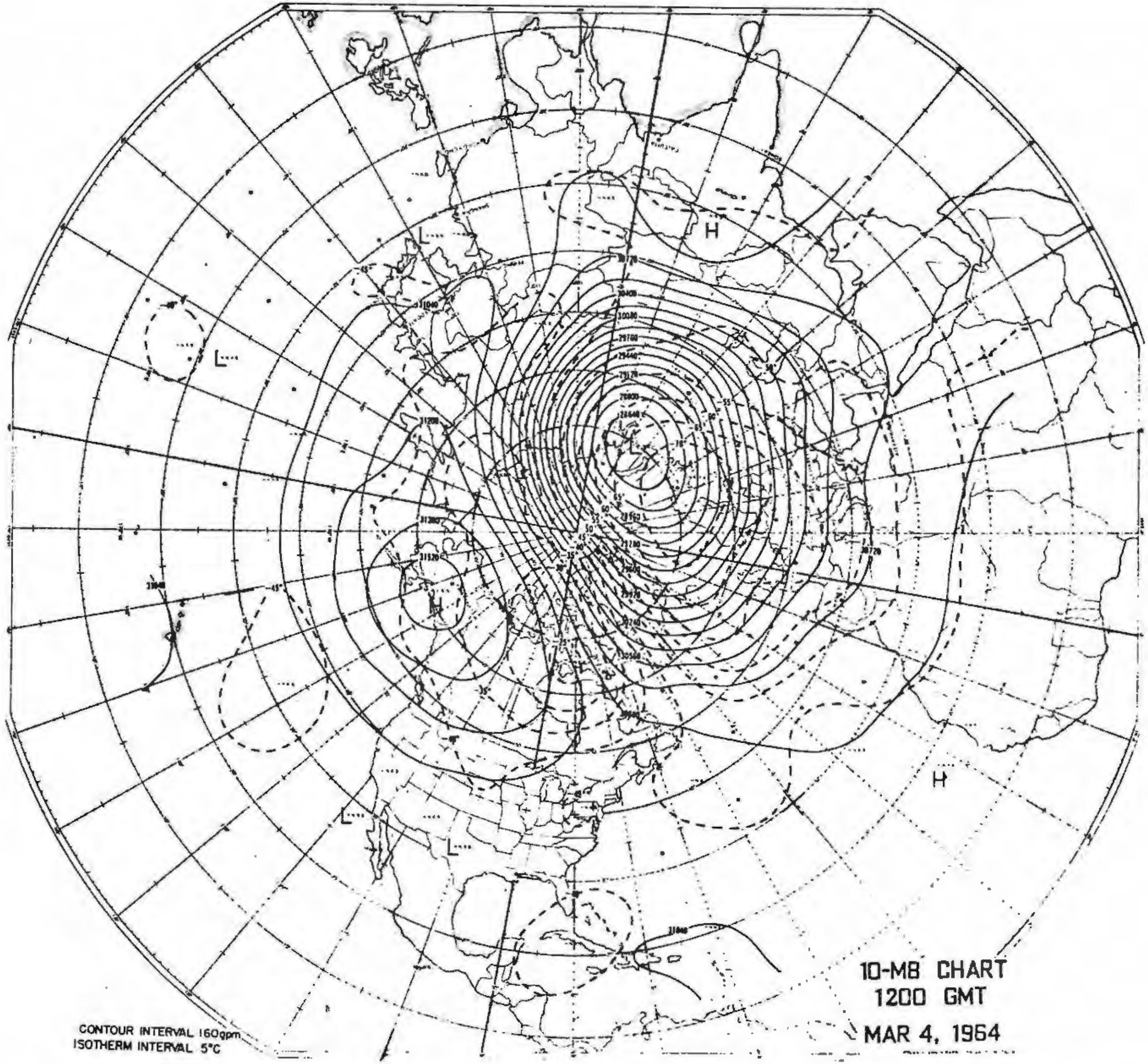

10-MB CHART
1200 GMT
MAR 4, 1964
CONTOUR INTERVAL 160gpm
ISOTHERM INTERVAL 5°C

Fig. 6

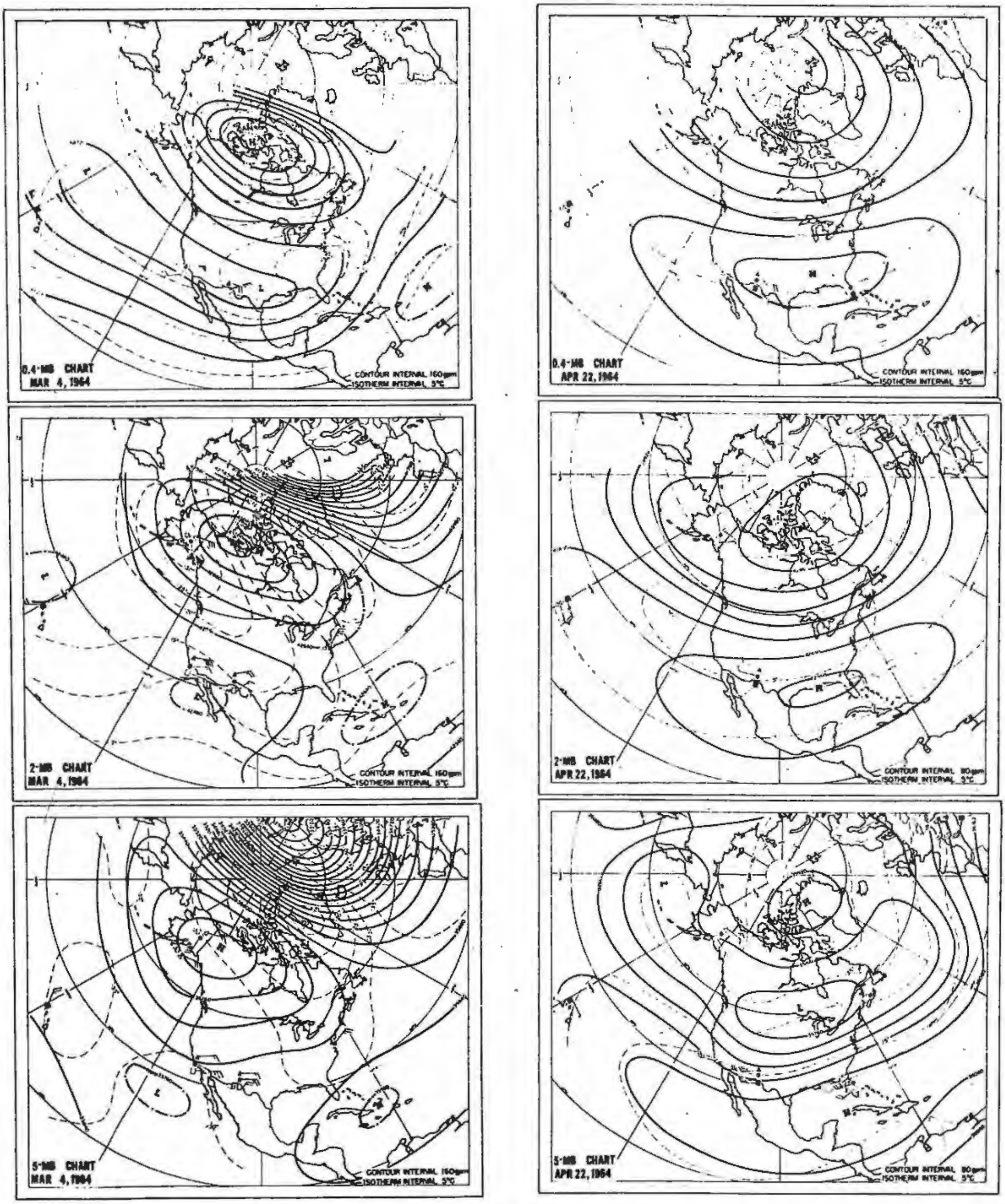
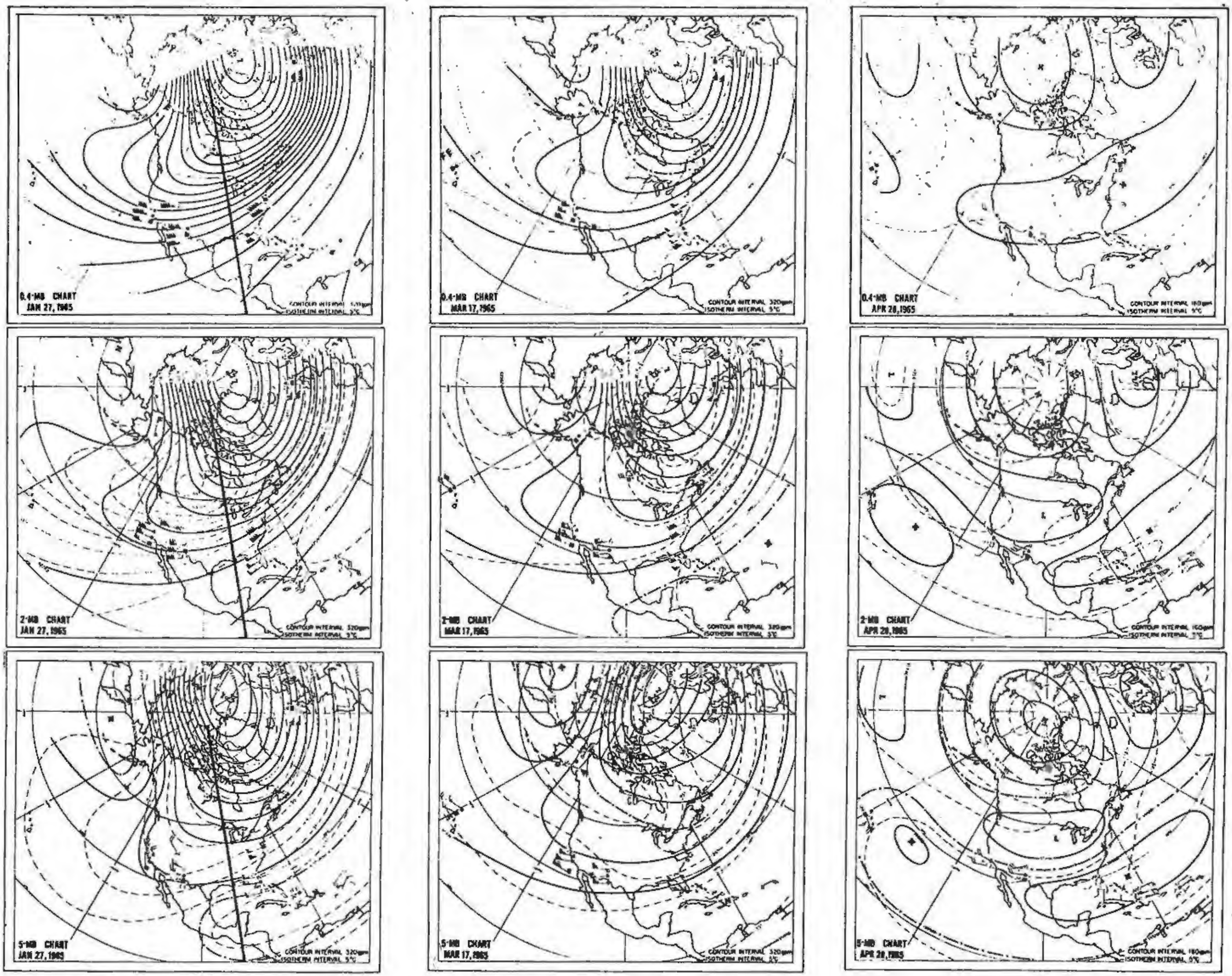

0.4-MB CHART
MAR 4, 1964
CONTOUR INTERVAL 160gpm
ISOTHERM INTERVAL 5°C
0.4-MB CHART
APR 22, 1964
CONTOUR INTERVAL 160gpm
ISOTHERM INTERVAL 5°C
2-MB CHART
MAR 4, 1964
CONTOUR INTERVAL 160gpm
ISOTHERM INTERVAL 5°C
2-MB CHART
APR 22, 1964
CONTOUR INTERVAL 80gpm
ISOTHERM INTERVAL 5°C
5-MB CHART
MAR 4, 1964
CONTOUR INTERVAL 160gpm
ISOTHERM INTERVAL 5°C
5-MB CHART
APR 22, 1964
CONTOUR INTERVAL 80gpm
ISOTHERM INTERVAL 5°C

Fig. 7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JAN 27, 1965
0.4-MB CHART
MAR 17, 1965
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APR 28, 1965
2-MB CHART
JAN 27, 1965
2-MB CHART
MAR 17, 1965
2-MB CHART
APR 28, 1965
5-MB CHART
JAN 27, 1965
5-MB CHART
MAR 17, 1965
5-MB CHART
APR 28, 1965

Fig. 8

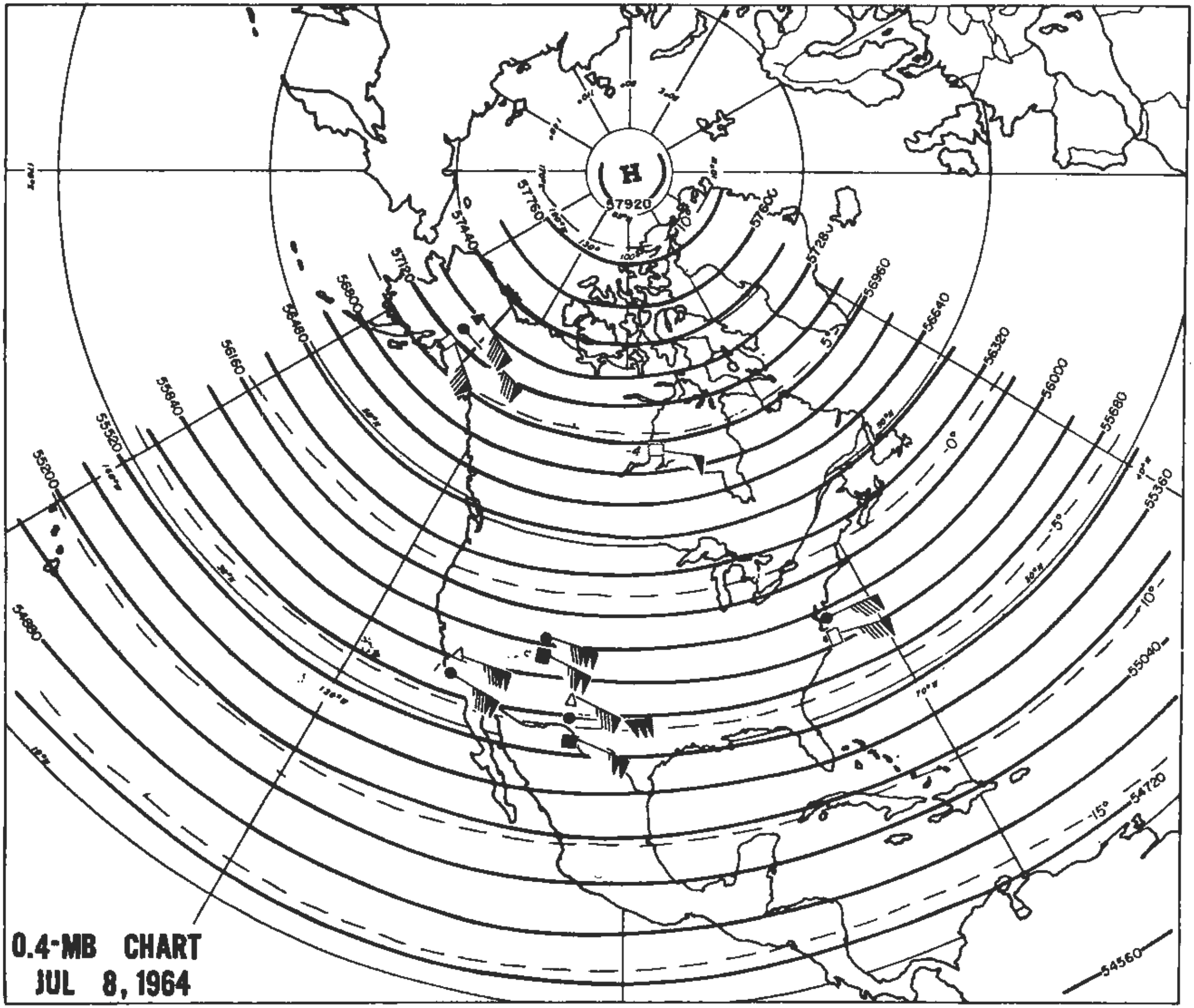

Fig. 9

CHIEF ADMINISTRATION OF HYDROMETEOROLOGICAL SERVICE OF THE USSR

AT THE COUNCIL OF MINISTERS OF THE USSR

12 PAVLIK MOROZOV ST., MOSCOW D-376, USSR

#M-115

March 29, 1967

To Dr. A.W. Brewer,
President, Canadian Meteorological Society.

Dear Dr. Brewer:

I beg you to accept my sincere congratulations in connection with the foundation of Canadian Meteorological Society and I wish every success to its activities.

I am grateful for the issues of the "Atmosphere" you mailed to me. I am very pleased to see that Canadian colleagues are interested in the activities of our scientific establishments.

I am enclosing a copy of my paper titled on the Rational System of Hydrometeorological Information in the hope that it may be of some interest to you.

Most sincerely yours,

E.K. Feodorov,
Academician,
Hydromet. Service of the USSR.

A RATIONAL SYSTEM OF HYDROMETEOROLOGICAL INFORMATION

By E. K. Feodorov, Academician, Director
of the Hydrometeorological Service of the U.S.S.R.

(Translated by A. Nurklik from Meteorologiia i Gidrologia, #11, 1966)

The operational and scientific activities of the Hydrometeorological Service are based on gathering, processing and analysing a vast volume of information on the state of the atmosphere and the hydrosphere. About 70 per cent of our budget is spent on these activities. It is therefore natural that a rational organization of these functions is a rather serious problem to us.

It should be noted that although the technological progress tends, in general, to reduce the dependence of man's every day activities on the natural phenomena, it demands a greater volume and more detailed information on the state of the environment. With respect to the number of environmental parameters as well as to their space and time resolutions. The availability of modern technological facilities expands rapidly the environmental information-gathering capability and reduces, in general, the cost of information acquisition and its analysis. It follows from obvious considerations that the Service must aim at an observational system capable of producing the necessary environmental information with a minimum number of quantitative measurements of parameters involved.

Most of the presently-used forms of hydrometeorological information and the methods of obtaining it have historically come into being as the result of the realization of the available possibilities and not as the result of an analysis of information requirements. We observe the precipitation, and compute evaporation, measure the wind at the height of some meters and calculate its value for some tens of meters of height, not because we are convinced that this is the proper way to do it, but because this was the only way it could be done several decades ago. In the same way, we are accustomed to get information on the state of the atmosphere over continents from an extensive network of fixed stations. In contrast to this, we have been accustomed to get similar information for oceans from mobile stations organized on merchant and research ships and to widely use averaging and reduction of data to certain geographical points over the ocean, although they were taken at some distance from them.

Principally, we have been accustomed to determine the state of the atmosphere, throughout its entire depth, but in particular the cloud conditions, from the ground observations. Therefore, the mastering of new technological possibilities brought about by meteorological satellites (observations from above) requires some effort.

It should be noted that in many cases tradition and habit dictate to us to present the information obtained by principally-new methods and technological facilities still in the old accustomed form instead of developing basically new forms of information.

Disclosures of relationships between the atmospheric processes in recent decades have had no effect on the information gathering systems. The atmospheric processes are interrelated; they bring about motion and changes in the state of the same physical body - the atmosphere. Generally speaking, these relationships enable one to determine the values of some parameters from the measured values of others, and the more relationships between the atmospheric processes are disclosed, evidently, the less direct observations are necessary for the characterization of the atmosphere as a whole. Therefore, it would have been natural to expect that progress in meteorological science has led to a gradual elimination of systematic observation of some meteorological elements. Actually, this has not been the case. New observation methods and instruments have been devised and the observation of new elements have been added without the exclusion of old ones. In spite of our understanding of the atmosphere as a whole, we still measure its individual features and study many of its phenomena as independent variables.

In trying to define the volume and the space-time resolution of meteorological information necessary and adequate for the operational work and scientific research, we utilize the studies in recent decades on the spatial fields of various meteorological elements. For instance, the latter have been used for the determination of the optimum density of the network for the observation of air temperature, pressure and some other parameters. However, it is evident that these studies facilitate the determination of the network density which satisfies certain requirements presented to the information, but have only a secondary importance from the standpoint of developing and formulating the actual requirements.

We have some ideas on the desirability of additional information and we sometimes devise actual methods for obtaining it. For instance, at the present much attention is given to the methods of obtaining information by means of meteorological satellites. However, there is not as yet a precise idea on the volume of information necessary and sufficient for the total activities of the Hydrometeorological Service.

In connection with this, there are a number of shortcomings in the existing system of obtaining and analysing the information on the state of the atmosphere and hydrosphere. There is some truth in statements that some observations, for instance, the measurement of air temperature and pressure, are made with an unnecessary accuracy. At the same time, such important characteristics of the atmosphere as the wind is not observed in the entire range of its variation, and precipitation is measured with an insufficient space resolution. Extremely insufficient is the present information on the subterranean water, particularly on its dynamics.

We care also too little about the precise determination of the future requirements of the national economy for the hydrometeorological information in connection with its perspective development and progress. Of course, the present day system of observing the parameters of the atmosphere and the hydrosphere has historically come into being not accidentally, but taking into account the operational and scientific requirements of the time. Nevertheless, its development occurred not on the basis of an integrated plan designed for this purpose but gradually, and most often, lagging considerably behind the contemporary requirements and without a co-ordination between its various constituent parts. Therefore, the existing information system cannot be considered adequately justified from the scientific and technological points of view without special testing and computations.

In the last analysis, all information gathered is used to satisfy the needs of the actual activities of the Service. However, only a small portion of the initial information is used in practical applications in the form it was received. Ordinarily, the information received is processed, generalized and used for weather forecasting and for various reference publications. We designate the latter as the derived information. A small portion of the initial information is not used at all for operational purposes but is accumulated for scientific research and becomes available for the operational work only through the results of scientific research.

It is evident that in order to be able to formulate justified technological requirements for the hydrometeorological information acquisition system, we must, first of all, precisely know the needs of the principal branches of the national economy for initial and derived information. We must also formulate precisely the requirements of the Service with respect to the initial information which is necessary for the scientific research of the Service and for the production of the derived information.

Can we formulate these requirements? In some cases we can. However, in most cases we have not unfortunately been as yet concerned about a more precise determination of these requirements; we are only expressing them more or less correctly in vague qualitative terms.

Thus, for instance, the present day requirements of aviation with respect to hydrometeorological information have clearly been outlined. The hydrometeorological elements which determine the current and future weather on an airfield and along a route, the required and sufficient accuracy of their values have clearly been designated and substantiated as the result of a long, close co-operation between meteorologists and aviation experts. For instance, we understand very well that the cloud height data in an aviation forecast must refer to the area and time where and when the aircraft makes the landing approach.

By knowing the precisely outlined actual requirements of aviation we can rationally devise proper measuring devices, measurement methods and forecasting techniques. We meteorologists, as well as the aviation people, are aware of the limitations of the present day meteorological service in satisfying the needs of aviation and of the effectiveness of our activities in this field.

A different condition has developed in providing hydrometeorological service to agriculture. Let us consider here only the precipitation measurement. At the present, as one hundred years ago, it is well known that the development of agricultural crops depends considerably on the moisture. The precipitation data have for a long time been used for the evaluation of crop conditions and the planning of agricultural economy. Nevertheless, we still don't have a clear conception on requirements we must present to the space and time resolution of precipitation data. How large is the area around a rain gauge for which the precipitation amount measured by it during a certain period is representative?

It is easy to see that the same precipitation measurement system may simultaneously be satisfactory and unsatisfactory depending on whether we want to estimate the precipitation amount for each 1000 km. or 1000 hectares (= 2.471 acres), for a season, decade or each storm.

It is evident that the requirements of the agricultural industry with respect to the type of hydrometeorological information are multivarious depending on the purpose the information is used for and the branch of the industry. The information required for a preliminary estimation of possibilities of raising a certain crop variety in a certain part of the country is of a different nature than that necessary for the forecasting of crop yields in fields of a farm. However, by analysing all basic requirements, we must be able to isolate the most important of these requirements which then determine the nature of the required information.

A similar condition exists also with respect to the hydrometeorological information requirements of the building industry and of many other sectors of the national economy. It is naive to expect from our customer-users a detailed summary of their hydrometeorological information requirements. Of course, they know what they want but often they cannot correctly consider our capabilities in obtaining and preparing the requested information and they don't know, and are not required to know, the relationships and connections between the phenomena occurring in the atmosphere and the hydrosphere. It is likely that a large part of the effort involved in drafting the hydrometeorological information requirements of the various branches of the national economy must be borne by our specialists familiar with providing service to these branches. However, it seems to us that the approval of the requirement list by the national economy branch involved must be sought at the final stage of the drafting.

In drafting the hydrometeorological information requirements of a branch of the national economy, one must not only know the information necessary for it but also have a clear idea of what happens if this information is not provided. For instance, we know that the wind data for the 10-500m. layer are necessary for many branches of the national economy. However, before accepting the wind observations in the boundary layer as necessary, one must answer the following questions: how necessary are these data at the present time and how big losses accrue to the national economy from the inavailability of this information? Is it necessary to take definite steps at the present time for the initiation of wind observations in the boundary layer at many stations? How big losses accrue to the national economy from not knowing the maximum wind speed in the boundary layer and how soon must this condition be rectified?

We must, without fail, produce soon an exact picture on the present and future requirements of the basic branches of the national economy with respect to type and volume of environmental information.

A successful advance planning of the development of various branches of the national economy requires some general knowledge on the future regimes of certain meteorological and hydrological elements in various parts of the country during the next decades and even during the next 100-200 years. In some cases, it may be necessary to estimate the possible changes in the hydrometeorological regime due to the planned expansion of the economy, for instance, variations in water balance and in some climatological factors that may result from the construction of large hydroelectrical power complexes, artificial irrigation systems and drainage of large swamp areas.

Let us assume that the basic hydrometeorological information necessary for the planning of any branch of the national economy must be collected and generalized for the entire country in the framework of the normal and regular functioning of the information acquisition system of the Service without a need for the initiation of long lasting special observations; otherwise the lack of data would significantly hinder the planning of the national economy.

The design of large constructions or other measures also requires data on the future trends in regimes but on a more detailed scale and for a particular locality. However, it is hardly possible to organize the work of the Hydrometeorological Service in a manner that it is, at all times, capable of giving environmental information for any locality of the country in a detail that is sufficient for the actual designing. It is evident that in this case the collection of necessary additional data, that supplement the basic data and satisfy the actual requirements of a project involved, must be organized. The Hydrometeorological Service has often been asked to initiate additional information gathering, for instance, for a detailed study of agricultural peculiarities of a region and of air and water pollution in industrial areas; for planning of new industrial complexes and communities around them, for the computation of maximum discharges of water bodies, for the evaluation of maximum ice and wind loads on the high tension electrical transmission lines, etc. Sometimes a proper processing of already available basic data produces the required information, at other times and circumstances supplementary observations have to be organized.

In some cases, it is expedient that the required hydrometeorological information is prepared by the establishments of the Hydrometeorological Service, in other cases directly by the designing establishments. We must have some idea about the future volume of this type of activity in order to rationally plan its acquisition by various interested agencies. We must study this question, determine the type and the volume of necessary information for basic types of projects, and, in co-operation with the designing agencies, formulate a perspective plan for their realization. This activity must be started right now keeping in mind also the future requirements of the national economy.

Current activities of the national economy, managing of enterprises, installations and transport systems pose specific demands on the information used directly for practical purposes as well as for various calculations and forecasting. Issuing of advisories on harmful and dangerous phenomena occurring at the present time or that occurred in the immediate past, forecasting of phenomena for periods ranging from several minutes to several months constitute the main elements of the intelligence necessary for servicing the current activities of the national economy.

Of considerable importance is the urgency of the required information. It depends principally on the speed of transport systems involved, on their vulnerability to the environmental elements and on the variability of the properties of these elements.

At the present time, aviation has the greatest urgency for meteorological information. Its requirements are critical regarding the detailing and accuracy of short-range weather forecasts.

The critical level of the accuracy and the advance time of long-range weather, river and marine forecasts are determined by the requirements of the agricultural industry, mercantile marine, hydroelectric power stations and, in general, by the utilization of water resources.

Compilation of all requirements of the basic branches of the national economy enables one to compose an integrated list of technological requirements with respect to initial and derived information (various reference books, forecasts, etc.), the Service must provide to the national economy.

Furthermore, we must also examine the requirements of various departments of the Service with respect to the observational information used for the production of various forecasts and reference materials.

It is evident that we must examine, in the first place, the initial information requirements from the standpoint of forecasting.

This problem has recently been studied in papers by specialists, mainly by those active in the field of numerical weather prediction. So far, only the specialists engaged in the short-range weather prediction have formulated their requirements to the information acquisition system. However, it should be obvious, without special arguments, that we must start to pay particular attention in our information acquisition plans to the requirements of the long-range weather forecasters. In connection with this, let us consider some circumstances. At the present, the short-range and long-range forecasting of atmospheric processes whether by numerical or synoptic methods is actually an extrapolation of the past state of the thermobaric field of the atmosphere (at a given time instant or averaged over a period respectively) into the future. It is well known that in doing this, the flux of heat into the atmosphere, the interaction between the atmosphere and the underlying surface, moisture circulation and some other factors which undoubtedly influence the atmospheric processes are not yet taken into account directly.

This state of affairs is admissible when considering atmospheric processes during short periods or when devising short-range weather forecasting models but it is inadmissible when considering atmospheric processes over longer periods. Many recent studies in the field of long-range weather forecasting have demonstrated the great role of these phenomena. Should'nt we be concerned about obtaining the information which would enable us, in the near future, to incorporate into our forecasting models the phenomena mentioned above? It may well be that the data on land and sea-temperatures over large areas and the information on radiation balance components, etc., are required for that purpose.

In examining the information requirements arising from the compilation of reference materials, the problem of the term normal presents great interest. The normal value* of meteorological and hydrological values must be taken into account in designing and planning the multitude of various measures and buildings for the rational economy.

At the present time, the long-term averages of meteorological and hydrological elements are considered as normals. This concept would be correct if the climate does not change. However, we definitely know that it changes. Should not we produce, instead of climatic normals, the prognostic future values of meteorological and hydrological parameters even on the basis of a crude extrapolation of their secular variations? Would not they, in spite of their approximate nature, satisfy better the needs of the national economy than the presently used normals?

Another interesting problem that deserves attention in examining the hydrometeorological information acquisition system is: what information is best to observe and what is best to calculate? In other words, how and in what cases must one utilize the known relationships between hydrometeorological phenomena for the information acquisition instead of observing them as independent variables?

So far, we have not paid enough attention to this problem. For instance, we observe clouds, precipitation and visibility at thousands of stations but we measure the radiation balance components: the total, direct, reflected, diffuse, etc., radiation only at a few hundred stations. It is easy to understand that knowing the cloud type and amount, the precipitation amount and visibility, we can compute many, if not all, components of the radiation balance. The quantity and composition of the incoming solar radiation at the boundary of the atmosphere is well known and constant in the visual and infra-red spectral ranges. Only the presence of clouds and various aerosols in the atmosphere change the spectral composition of the solar radiation arriving at the underlying surface. The nature of the latter determines the amount of the solar radiation that will be absorbed and reflected by it and the intensity of the infra-red radiation emitted.

It may be more expedient to measure the radiation balance components at some tens of stations situated in different physicogeographical regions in order to study and improve the computation techniques. The values of radiation balance components at any point within a physicogeographical region could then be computed.

Is it not also better to use known methods of computing the soil temperature at various depths instead of measuring it at thousands of stations?

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*The author means under normal values the aggregate of the average, the most probable, the extreme, etc. values used for the characterization of regimes.

On the other hand, does the information on evaporation obtained now essentially by computational techniques satisfy us? Is it not proper to calculate the maximum wind velocity instead of measuring it?

Now we ought to carefully compare various possible information acquisition techniques in order to utilize the known relationships between various hydrometeorological elements excluding the doubtful relationships. It is evident that one must use the aggregates of hydrometeorological phenomena which compose the radiation, heat and water balances. It may be assumed, that the system of observations adopted will provide enough information for the determination of each term of these balances, and that the current practice of the measurement of the balances itself may serve as a good check of the reliability and accuracy of the measurements.

An important problem in devising a rational system of hydrometeorological information acquisition is the application of point data for the evaluation of phenomena in space. The work experience and tradition of the Hydrometeorological Service have grown on the basis of observations at network stations, i.e., at fixed observation points. However, whatever operational or scientific problem we tackle, the characterization of hydrometeorological processes or the parameter values at any point in the area or over the area involved are needed. For instance, it is more important to know, even if approximately, the extreme wind velocity in a hurricane at the point where it occurred than the exact extreme of wind velocity at a nearby station. The same reasoning is true also for the precipitation amount, temperature and for any other hydrometeorological parameter. We must have reliable techniques for going over from measurements at points to the characterization of phenomena in space. Until now we have not given serious consideration to this problem. For instance, in evaluating the soil water resources in fields of a district or province, we generalize the soil moisture data measured in the field of one station for areas of about 150-200 thousand hectares (≃ 600-800 square miles) without having sufficiently reliable data on probable errors involved and without determining the nature of soil moisture distribution over the given area.

Sometimes, the transition from measurement at stations to the evaluation of phenomena over an area is of a conditional nature. Some prognostic relationships may serve as an example. For instance, the flood forecasts must take into account the snow supply stored in a river basin. The calculation of the flood level depends entirely on the accuracy of the determination of this supply. In many cases however, we do not actually calculate the snow supply stored in a river basin, we only establish a statistical relationship between the water equivalent of snow measured at few stations and the river levels or discharges at characteristic points on a river during flood periods. Thus, we are not operating with the snow supply actually measured in a river basin but with a parameter that characterizes this supply. However, this procedure becomes reliable only when we have voluminous observational data, i.e., long records. In the latter case, we are not even particularly concerned about actual data. The stations chosen by us for the establishment of relationships need not even be situated in the river basin involved, although this statement seems to be absurd at first glance. If the snow supply at the latter stations is statistically representative for a river basin, the flood forecasting for it will also be successful.

In a similar manner, we relate the number of surviving winter crop stems counted and the soil moisture measured at a few stations with the average yields of winter crops over large areas. There is no direct physical and computational relationship between the above quantities but only a statistical relationship, the accuracy of which depends on the volume of data, i.e., on the length of data period. These procedures were admissible in the past, because no possibilities existed for obtaining actual values. However, such indirect methods cannot be tolerated in the future.

We must, as soon as possible, go over to relationships between the actual values. This means, for instance, in flood forecasting, the determination of the actual snow supply in a river basin and the obtaining of data which enable one to calculate the percentages of the snowmelt water that contribute to the river level and that which infiltrates into the soil.

The methods of obtaining and analysing information must also permit one to relate the measured values to certain meteorological entities. We consider the air masses and fronts as mobile and variable physical objects. In analysing and studying these entities we naturally want to refer to them the characteristics of various related phenomena. For instance, it is significant to survey precipitation amounts produced by the cloud system of a given front or the energy variations in a certain air mass associated with the given pressure system, etc. The present information acquisition and primary analysis systems relate data to the co-ordinate system fixed in space. It is evident that we must learn to dissociate the information from the fixed network and to refer the measured characteristics to processes or entities occurring in the atmosphere, rivers and seas.

We have already discussed above, the precision and the time and space resolution requirements of hydrometeorological measurements. Should one define certain fixed values for them in the rational information acquisition system? Would it not be more correct to strive for the condition where the space and time resolutions of measurements were dependent upon the nature of the phenomena involved? For instance, frequent detailed pressure measurements are hardly necessary in an area of a stable semi-permanent high but highly necessary in an area of a cyclone development and movement. At first glance, these suggestions seem to be too demanding for the observational network. However, the present day capabilities of the measurement techniques, data processing and analysis methods, enable one to devise an information acquisition system that has a variable space and time resolution.

Let us now consider some specific problems concerning the acquisition of information necessary for the study of hydrometeorological processes. Information acquisition has a great importance for research. Efforts spent on the information acquisition and on its preliminary processing for a given research problem constitute a great percentage of the total effort spent on the research of this problem.

Let us examine here a few simple scientific problems, the solutions of which are evident and the courses that led to solutions are, in principle, known. We shall refer to these problems as scientific-technical problems in contrast to the scientific-research problems, the solutions of which are not evident, and even the possibility of solving them in the near future is in doubt.

The number of scientific-technical problems handled by our scientific-research establishments is very great. One of such problems is, for instance, the attempt to establish correlations between meteorological parameters and the development of agricultural crops, in particular, those between meteorological parameters and crop yields. We know that such correlations exist and that they can be determined. The complexity of the problem consists in that, apart from meteorological factors, the crop development depends also on many other factors, like plant species, agrotechnical level, soil condition, crop rotation, etc.

The determination of the nature of showers in various parts of the country belongs to the same group of problems. Here we may be interested in the duration, peak intensity, total amount and the areal extent of showers, in the percentage the showers constitute in the total precipitation amount and also in other characteristics that may be needed, for instance, for designing some installations.

A similar but a more complex problem is the study of detailed peculiarities of the development of low clouds and fog in airport areas in connection with synoptic situations. As is known, the characteristics of low clouds must be forecast for airports in great detail, for instance, the cloud base height with a tolerance of few tens of meters. It is necessary to investigate whether there is a relationship between still more detailed cloud characteristics and the synoptic patters. If it turns out that certain cloud characteristics cannot be related uniquely to synoptic situations, one may still succeed in estimating the possible variations of cloud base height under certain synoptic conditions which would also be quite useful operationally.

A further example for the scientific-technical problems is the study of factors controlling the development of spring floods in a river basin. Here, it is necessary to clear up the relationship between the flood level and the hydrograph, snow supply, soil properties and water content, rate of snow melt, etc.

An example of methodical scientific-technical problems is the devising and testing of aerial snow survey techniques being currently carried out by the Service. Here, it is necessary to establish the probable error of the measurement and to produce actual radiometric techniques for the snow depth and density survey from an aircraft.

One may mention a host of other scientific-technical problems. In essence, we deal always with the scientific-technical problems, since the solving of scientific-research problems most frequently reduces itself, in the long run, to solving a number of scientific-technical problems.

The most correct procedure for attacking scientific-technical problems would be: the formulation of a quantitative theory of the process involved, and after that, the gathering of information necessary for obtaining numerical values of parameters. This procedure is applied sometimes. However, more frequently only an approximate qualitative model of the process studied is available and we determine empirically the necessary numerical parameters by statistical processing of observational data. In particular, for this type of investigation we need special observations.

It is evident that the nature of special information is different for different problems. However, one can express some general considerations on its nature. We note, firstly, that a large volume of information is needed in order that the computed parameters have an adequate statistical reliability. Secondly, the relationships studied change in time and space and, as a rule, vary differently in different geographical regions. Hence, the tendency exists to lengthen the observational period and to arrange observing points all over the territory. However, the characteristic long acquisition period is by itself an extremely negative feature.

At the present time, we utilize for research essentially the same observational data we use for operational activities. However, special (thematic) observations have been organized at many stations in addition to the ordinary observational program. We have hundreds of such stations. The supplementary information for the solution of scientific-technical problems in the domain of meteorology, hydrology, agrometeorology, etc. is gathered separately from the information of the ordinary observational program. The corresponding observations are organized independently at various network stations, so that these observations cover more or less uniformly the territory of the country and enable one to take into account the different phsicogeographical conditions. Special networks and the supplementary (thematic) observations constitute a rather great percentage of the workload of our observing staff. The special observations have enabled us to solve a large number of scientific problems. However, the solving of each of these problems has taken a long time, some years, even some decades because we wanted to base our research on columinous statistical data. Sometimes, special observations and the problems themselves have been forgotten.

Can such systems be regarded as justified?

In order to speed up the solution of long-ago formulated scientific-technical problems that still confront us today, it seems to be expedient to change the data acquisition system. Would it not be more effective to gather special information for the solution of a given problem than for many problems? This would ensure the accumulation of necessary data in a shorter period, say, in a few years. It is very important to reduce the length of the information acquisition period ensuring, at the same time, an adequate time and space resolution of information by organizing a great number of observing station. However, it is evident that the latter cannot be done all over the country. Therefore, it is necessary to organize the requisite temporary network in the form of experimental ranges (polygons) in various characteristic physico-geographical regions in the country in order that the effect of the latter can be studied. The size of experimental ranges must correspond to the space extent of the process studied. Let us consider, for example, the investigation of showers. The information available on this topic stems mostly from the recording rain gauge network and, to a small extent, from a few small shower observing networks. However, the recording rain gauges in the ordinary meteorological network are separated from each other by a distance of several tens of kilometers. On the other hand,we know that the horizontal extent of the cloud system producing showers is quite small. The character of showers changes sharply, not only in the extent of kilometers, but also in the extent of a few hundred meters. Thus, the sparse network of recording rain gauges cannot delineate the size and intensity of a shower. One or two recording rain gauges, being situated in the shower area, produce only random information and the maximum amounts of rain recorded by them do not necessarily indicate the absolute maximum amount of rain produced by this shower. It is evident that with the ordinary recording rain gauge network, certain conclusions concerning the intensity and frequency of showers, can be made only after a very long period of observations. However, if we organize a network with an optimum density of recording rain gauges over an area several tens of kilometers in diameter, then, even a relatively short period (of the order of some years) operation of such a network enables us to study, with an adequate resolution, a considerable number of showers.

The study of the effect of meteorological parameters on agricultural yields is carried out at the present time with the data of ordinary network stations assigned to take agrometeorological observations. The observation program of these stations includes, in addition to the regular meteorological observation program, phenological and soil moisture observations and the evaluation of crop conditions and yields in the corresponding fields. The resulting data are more or less adequate for issuing the crop condition advisories and yield forecasts but inadequate for research already because the precipitation, soil moisture and crop conditions are observed at points separated from each other by a distance of the order of kilometers. It is well-known that in the central part of the Soviet Union the difference in precipitation amounts at points separated by a few kilometers may amount to several hundred per cent even for a season. Therefore, a vast volume of observational data is necessary in order to derive from it any reliable conclusions.

The agrometeorological observation system effected in experimental ranges (polygons) in recent years may considerably facilitate this type of research. The experimental ranges encompass large areas some hundred kilometers in diameter, and are equipped with a rather dense rain gauge network. Here, a highly qualified evaluation of crop conditions and yields can be maintained. Inasmuch as experimental ranges also include ordinary forms, we can rely, with a high degree of confidence, on results obtained here. It is hoped that a limited number of such experimental ranges will suffice to consider the effect of physicogeographic conditions in the principal agricultural areas of the country. The experience gathered in recent years shows that this type of experimental ranges has been very useful for improving the precipitation measurement methods and for evaluating the measurement errors of the newest radar technique of precipitation measurement. Similarly, the river discharges have, for some time, been studied by means of smaller hydrological experimental ranges.

It is our belief that many atmospheric and hydropheric processes can be studied more successfully with the experimental range data than with the conventional network data. It is natural, that efforts must be made to instrument an experimental range so that the information acquired from it can be applied for the study of several problems. For instance, it is already evident that the study of agrometeorological problems, evaluation of precipitation measurement methods, cloud seeding problems and many others can be carried out in the same experimental range since each of these studies requires a high space resolution of processes occurring on a scale of several tens of kilometers.

A properly devised information acquisition system not only simplifies but, more markedly accelerates the solving of a host of scientific-research problems. Many difficulties in solving scientific problems stem not from the lack of possibilities, but from the lack of well formulated plans of attack.

The concepts expressed above deserve attention when devising a rational information acquisition system. Undoubtedly, some of these concepts are controversial, some of them may even prove to be incorrect under a closer examination. However, it is important that the specialists of our Service pay serious attention to them and take an active part in the rationalization of one of the most important sectors of our activity.

NOTES FROM COUNCIL

The following were accepted as members at the March 30, 1967 meeting of Council:

W.G. Ballantyne
N. Barthakur
C.S. Buffett
E.F. Caborn
J. Carpick
J.K. Chung (student)
K. Churches
W.J. Crowley
E.H.V. Dexter
G.L. Doerksen
D.J. Fedorick
M.G. Ferland
R.M. Gagnon
E. Gherzi
E.J. Gregga
K.M. King
R.J. O'Brien
G. Pech
J.J. Rahn (student)
J.H. Richards
R.J. Rodden
D.J. Schaefer
I.S. Selerco (student)
G. Vali
G.O. Villeneuve
L. Wojtiw

The following were accepted as members at the May 12, 1967 Meeting of Council:

W. Baier
S.K. Chakravarti
J.R. Clements
T.F. Gigliotti
W.R. Hamilton
V. Jelinek
K. Lee
E.J. Llewellyn
J.H. McCaughey (student)
M.N. Monsinger
L.E. Parent
R.J. Renard
J.H. Renick
Marie E. Sanderson
R.C. Schell
R.W. Shaw
J.L. Sullivan
C.I. Taggart
T.P. Wilkinson
M.G. Woodhead
F. Yasui

PUBLICATIONS EXCHANGE

During the spring of 1967, Society members were informed of the existence of a small stock of publications in Toronto and were asked to request any volumes needed to fill out personal or office libraries. Twenty-two requests for publications have been received and these have been filled as far as possible.

In addition to the requests for specific publications, some members indicated that they were in the market for spare copies or complete sets of Royal Meteorological Society and American Meteorological Society publications. Another member advised that his agency has spare copies of a number of issues of journals and periodicals. Contacts have been made and the individuals concerned have been asked to negotiate the exchanges on a personal basis.

There are, undoubtedly, more members who are anxious to build up a personal library of meteorological journals. There are also members who periodically look at shelves (or piles) of journals and wonder what they're going to do with them. If you are one of the latter group, please advise your Executive before you discard the publications. While they might not have much value to you, please remember that your collection is practically unobtainable to a young meteorologist.

If you have any journals or weather magazines to give away or if you are anxious to build-up your library, please write to

M.K. Thomas
Vice-President
Canadian Meteorological Society
315 Bloor Street, West
Toronto 5, Ontario

C.M.S. Plays Host to Delegates Attending the Chalk River A.E.C. Micrometeorological Information Meetings, Sept. 11-14, 1967.

The USAEC (United States Atomic Energy Commission) holds micrometeorological information meetings every few years at different nuclear research centres. This year, for the first time their meetings were held in Canada. It was hosted, and I might say very admirably, by the Environmental Research Branch, Chalk River Nuclear Laboratories at Chalk River, Ontario.

There was a large turn out of delegates (approx. 75) and many eminent names such as Prof. Ben Davidson of N.Y.U, Prof. H. Panofsky of Pennsylvania State University, Dr. Munn of the Canadian Meteorological Service and many others.

The meetings proved to be of much interest. There were sessions on plume rise, turbulence and diffusion, deposition and re-entrainment, transport, and scavenging. The papers presented at this information meeting are presently being prepared for publication.

Tuesday evening, Sept. 5, the C.M.S. played host to the visiting delegates. The program began with an introduction by our President, Dr. Brewer, followed by a short movie produced by Dr. Moroz of the University of Toronto, showing the effects of the lake breeze on a plume. This was followed by a short talk by E.I. Mukammal after which a 30 min. movie on the 500 ton blast at the Suffield Experimental Station was shown.

Dr. Brewer briefed the delegates on the short history of the C.M.S. and then went on to give his views on "The Future of Meteorology in Canada".

The time-lapse movie shown by Dr. Moroz was of much interest and created some interesting discussions. One interesting sequence of shots showed a plume rising almost vertically for a few meters, then forced inland by the off lake flow as it rose for a few more meters, thence flattening out and carried out over the water by the return flow from the land. He referred to this effect as the "question mark" effect.

Mr. Mukammal gave an interesting talk on his meteorological studies in a forest near Chalk River. During the previous day, the delegates were given a tour of his instrumented site. The site consisted of a meteorological tower extending to above the forest canopy with sensors of temperature, wind and humidity at various levels. One interesting apparatus was a trolley extending for a number of meters, two or three meters above the ground. This trolley was instrumented with two moving net radiometers.

A most interesting movie of the Suffield 500-ton blast trial was presented by O. Johnson of the Canadian Meteorological Service. The movie showed the preparation, the explosion (which was on the scale of a small A-bomb) and some of the results of the explosion.

The C.M.S. meeting ended with coffee and lively discussions.

M.S.H.

C. East - Fr. C. East, S.J., has been appointed Assistant Professor of Meteorology at the School of Hygiene of Université de Montréal. Apart from lecturing on air pollution meteorology and human biometeorology, Fr. East is conducting research projects into sulpher-dioxide concentrations over Montreal, and the urban heat-island effect there. (The project is sponsored by Dept. of National Health and Welfare.) Fr. East has also been appointed to Committee TA-8(Meteorology) of the Air Pollution Control Association.

MEETINGS

The Toronto Centre of the Canadian Meteorological Society held its first meeting for the 1967-68 season on Oct. 10 at 147 Davenport Road.

The 35 members present heard a very interesting talk given by Professor F.H. Theakston of the School of Agricultural Engineering at the University of Guelph.

The talk on Model Studies of Snow and Wind proved quite intriguing to the members. Professor Theakston described model experiments used to predict the pattern of snow deposited by wind in the vicinity of obstructions. The model uses a water flume and white sand to simulate air flow and snow. The advantage of this arrangement over wind tunnel experiment is the ability to reduce the speed of motion. The results are the same but the motion of the particles is easier to observe.

The application of this type of forecasting in agricultural, highway and industrial construction was shown and readily appreciated. The pattern prediction accuracy of 100 percent was the envy of many of the forecasters present.

W.D.L.

Thirteenth Radar Meteorology Conference

The Stormy Weather Research Group at McGill University will be host to the 13th Radar Meteorology Conference, 20 to 23 August, 1968. Previous conferences have been held at 18 to 24 month intervals since 1948. The last time the conference was held in Montreal was 1952.

The meetings are organized by the AMS Committee on Radar Meteorology. For this conference, NRC support has been promised, and the CMS has been asked to co-sponsor it with the AMS.

Preprints of the papers of the conference in abbreviated form will be distributed some weeks ahead to all pre-registrants. At the Conference, the presentation of the papers will be by invited rapporteurs, in the form of critical summaries designed to introduce discussion. Then, in the full discussion periods that follows, authors will be given pride of place. There will be no parallel sessions, and it is hoped to avoid evening sessions other than (possibly) special discussions.

The Conference dovetails with the International Conference on Cloud Physics, which will be held at the University of Toronto in the following week, 26 to 30 August 1968. The programs of both conferences will be planned in a cooperative way to avoid duplication, and to insure some complementarity. Prospective contributors and other participants at either conference are urged to bear the other meeting in mind when making their plans.

While the emphasis given to various topics will be adjusted to accord to the titles submitted, and while the proximity of the Conference on Cloud Physics will be taken into account, the meeting is expected to cover in one way or another the usual areas:

1. Storm studies
2. Precipitation measurement
3. Scatterning, polarization, attenuation
4. Radio climatology
5. Mesoscale analysis
6. Use of radar in forecasting
7. Techniques and instrumentation
8. Data processing

Titles of papers offered should reach the organizers by 15 January 1968; the titles of papers accepted tentatively will be circulated to contributors shortly afterward. Abstracts will be required by 28 February and the full camera-ready texts (2 or 4 or 6 pp) by April.

Accommodation will be available in University Residences (single rooms only, no bar, no air conditioning) and in nearby hotels.

Copies of this announcement and preliminary questionnaires are being sent to authors of papers presented at the Twelth Conference on Radar Meteorology, Norman, Oklahoma, October 1966. It is requested that others interested in the Conference write to Radar Meteorology Conference, Department of Meteorology, McGill University, Montreal 2, Canada, for a copy of this questionnaire.