AFCRL-65-846

WEATHER RADAR MAPS ON FACSIMILE AND NEW THEORETICAL STUDIES

J. S. Marshall

McGILL UNIVERSITY
STORMY WEATHER GROUP

FINAL REPORT

January 1963 to August 1965

Contract No. AF 19(628)-2489
Project No. 6672
Task No. 667205

OCTOBER 1965

Prepared for
Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

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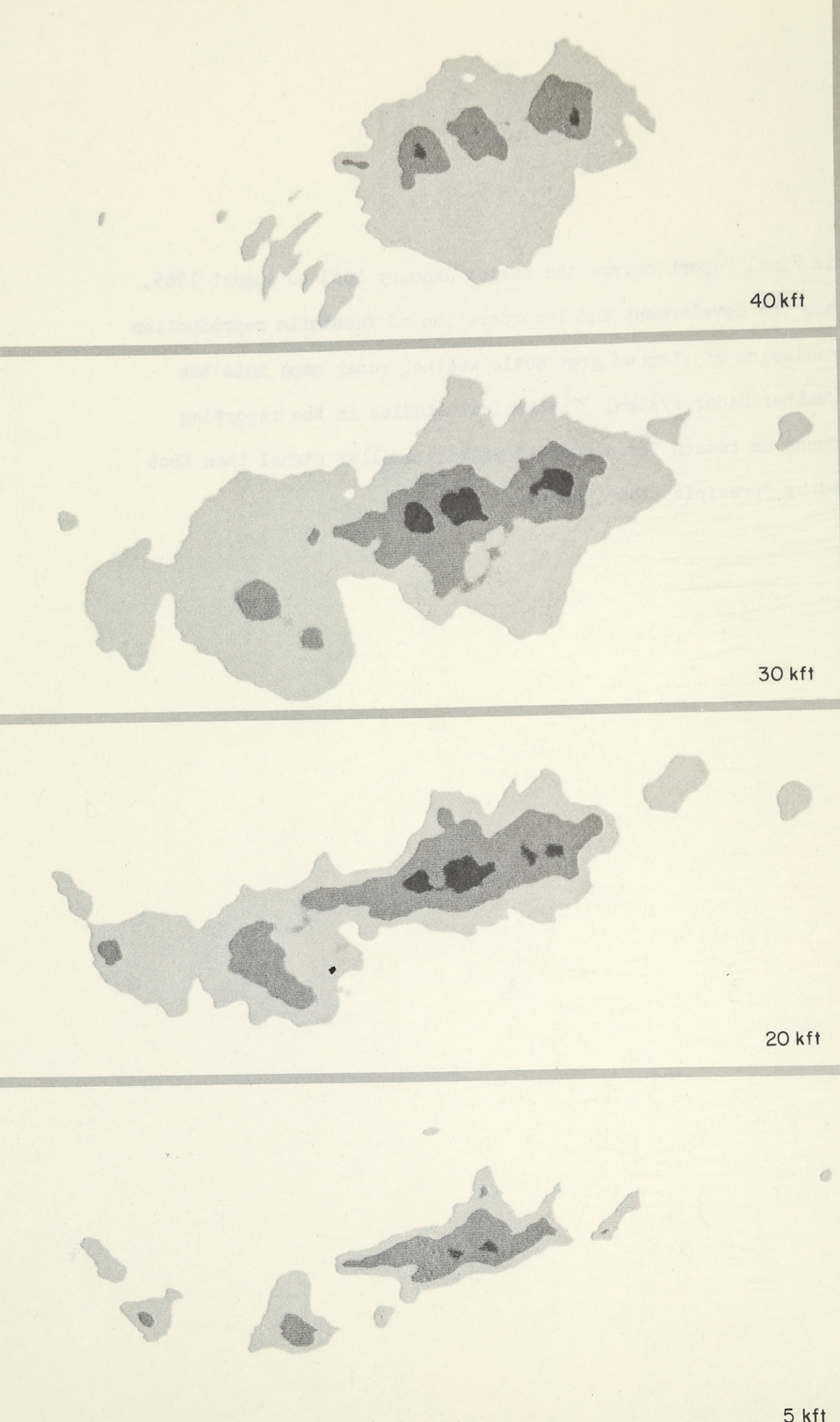
This Final Report covers the period January 1963 to August 1965. It reviews the development and incorporation of facsimile reproduction and transmission of stepped grey scale weather radar maps into the McGill Weather Radar system. Theoretical studies in the reporting period found no reason for clouds to yield a smaller signal than that indicated by "precipitation" theory.


40 kft
30 kft
20 kft
5 kft
18 JULY 1964
2057 EST
MONTREAL
SCALE
0
20 NMI

WEATHER RADAR MAPS ON FACSIMILE

An earlier final report for the period 1959-1962 (under Contract AF 19(604)-6617) covered the improvements in detail to a weather radar system incorporating CAPPI and grey scale, and fully automated. The major technical development in the present reporting period has been the incorporation of facsimile reproduction and transmission into the system. On the same completely automatic basis a facsimile receiver, remote from the radar console (across the airfield or in another part of town) displays CAPPI maps in grey scale and the whole system continues to work without adjustment for twenty-four hours or longer (Wein, MW-40). With the areal integration provided by the scanning spot and the consequent sharpening of the boundaries between grey shades, intensities can be read from the facsimile maps without any need for a reference scale of greys. Good distinction between grey shades was achieved in spite of the limited dynamic range of the facsimile paper by having twin maps side by side, the left displaying echo of intensity levels 1, 3, 5, and 7, and the right 2, 4, and 6. We had to develop our own slow-speed flying-spot scanner. Much effort went into this, and into the technique of using available facsimile equipment for grey scale, that would be unattended. Parallel to this work on scanning, transmitting and receiving work has continued on improving the reliability of the radar side of the automated system.

The illustration opposite shows excerpts from four of the six maps in our height sequence, reproduced about 1.3 times actual size. While there is some variation in the size of the intense cores of level 5 (darkest grey) in this thunderstorm complex and in level 3 (intermediate grey), the striking feature is the large area of overhanging echo aloft from the lightest precipitation.

During the last year of this contract, circuits originally devised by Canadian Aviation Electronics were revised by us (in relation to our equipment) to yield a set of seven grey bars with each pair of facsimile maps. Each bar gives the total area of one of the seven intensity intervals on that pair of maps. The bars related to six pairs of pictures at six standard heights give one set of the "profiles" that were first proposed by Hamilton and Marshall in 1961. This profile-generating equipment had just begun to work at the end of the contract period.

Apart from the profile-generating equipment, this whole automatic system has been in operational use continuously for two and one half years. Research on the records reported elsewhere (MW-37, MW-48) has concentrated on the records of the summer of 1963.

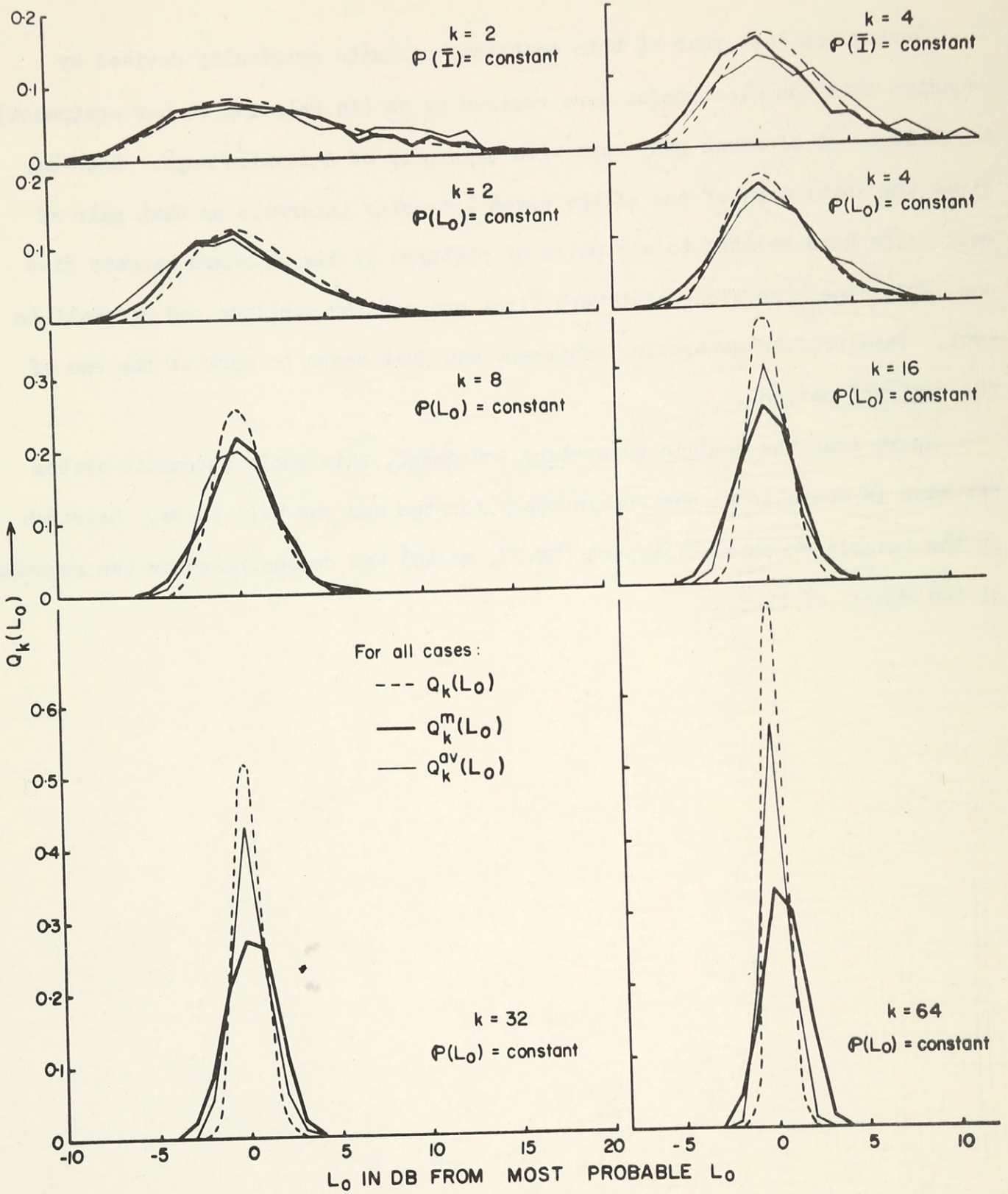


Fig. 4.7 Comparison of the probability distributions $Q_k(L_o)$, $Q_k^{av}(L_o)$ and $Q_k^m(L_o)$. For k = 2 and k = 4, curves are shown for both $p(L_o)$ = const. and $p(\bar{I})$ = const; for larger values of k, the differences between the curves would be insignificant.

NEW THEORETICAL STUDIES

Does the theory appropriate to radar returns from precipitation apply without correction to radar returns from clouds, recognizing that the spacing between cloud droplets is small compared with one wavelength? Back in 1953 we suspected that the returns from cloud would be different and that one could distinguish between the targets by the "texture" of their returns. We concluded (MW-4) that no such basis for distinguishing the two was available but went on to make a most valuable study of fluctuations in radar returns from such targets as precipitation and clouds. In the present period we have returned to the above question and done our best to find some theoretical reason for clouds yielding a smaller signal than indicated by "precipitation" theory. In our opinion there is nothing wrong with the theory. One small effort (by Lillesaeter, Nature, 202, 1103-4, 1964) considered situations when two scatterers are within a few diameters of each other. One knows the frequency with which this situation arises in a random array. Taking this occasional proximity into account yields a slight increase in average signal relative to the results of the basic theory. A larger effort (by Smith, MW-39) formed a bridge between two theoretical approaches, one of which considers signals from individual scatterers, and the other the departures of the medium from complete uniformity. His study turned up no likely departure from "precipitation" scattering results.

However, again there is a valuable by-product in the form of further consideration of target and signal fluctuations. Of greatest practical value, for signals on a logarithmic scale, the maximum value of the fluctuating signal is a good indicator of the desired average of many signal intensities. The figure opposite (Fig. 4.7, MW-39) shows that if the number of independent data

is less than 8, the maximum value (probability curve $Q_k^m(L_o)$) is a better indicator than the average ($Q_k^{av}(L_o)$), that is the average on a log scale. No alternative is quite as good as the actual average of intensities, but with a wide dynamic range this is very hard to come by. This practical use of "maximum level" in place of averaging can effect notable savings in circuitry, which we are looking forward to achieving.

P E R S O N N E L

The work summarized in this report has involved the following scientists and engineers:

J.S. Marshall	Project Director	1/6-time
K.L.S. Gunn	Physicist	1/10-time (on leave 64-65)
W. Hitschfeld	Physicist	1/12-time
Paul Smith	Physicist	NSF Fellow (63-64)
M. Wein	Radar Engineer	Full-time

Funds from the contract have also paid the major part of radar technicians' salaries and have contributed to a lesser extent to the support of scientific and secretarial assistants.

SCIENTIFIC REPORTS OF THE PRESENT SERIES

MW-1: Effect of particle shape and secondary scattering on microwave reflections from clouds and precipitation, by Milton Kerker and Walter Hitschfeld, March 1951.

MW-2: Measurement of snow parameters by microwaves, by J.S. Marshall and K.L.S. Gunn, May 1951.

MW-3: The modification of rain with distance fallen, by E. Caroline Rigby and J.S. Marshall, January 1952.

MW-4: Interpretation of the fluctuating echo from randomly distributed scatterers: Part I, by J.S. Marshall and Walter Hitschfeld, October 1951.

MW-5: Scattering and absorption of microwaves by a melting ice sphere, by M.P. Langleben and K.L.S. Gunn, March 1952.

MW-6: Interpretation of the fluctuating echo from randomly distributed scatterers: Part II, by P.R. Wallace, December 1951.

MW-7: The microwave properties of precipitation particles, by J.S. Marshall, T.W.R. East and K.L.S. Gunn, July 1952.

MW-8: Precipitation trajectories and patterns, by J.S. Marshall, M.P. Langleben and E. Caroline Rigby, August 1952.

MW-9: A theory of snow crystal habit and growth, by J.S. Marshall and M.P. Langleben, July 1953.

MW-10: The modification of rain in showers with time, by E. Caroline Rigby and J.S. Marshall, March 1953.

MW-11: A mathematical treatment of random coalescence, by Z.A. Melzak and Walter Hitschfeld, March 1953.

MW-12: Errors inherent in radar measurement of rainfall at attenuating wavelengths, by Walter Hitschfeld and Jack Bordan, June 1953.

MW-13: Radar evidence of a generating level for snow, by K.L.S. Gunn, M.P. Langleben, A.S. Denis and B.A. Power, July 1953.

MW-14: Initiation of showers in cumuli by snow, by A.S. Denis, July 1953.

MW-15: Turbulence in clouds as a factor in precipitation, by T.W.R. East and J.S. Marshall, July 1953.

MW-16: The terminal velocity of snow aggregates, by M.P. Langleben, January 1954.

MW-17: Development during fall of raindrop size distributions, by E. Caroline Rigby, K.L.S. Gunn and Walter Hitschfeld, January 1954.

MW-18: The effect of wind shear on falling precipitation, by K.L.S. Gunn and J.S. Marshall, December 1954.

MW-19: The convection associated with release of latent heat of sublimation, by R.H. Douglas and J.S. Marshall, December 1954.

MW-20: A: Size distribution generated by a random process, by Walter Hitschfeld.
B: The distribution with size of aggregate snowflakes, by K.L.S. Gunn and J.S. Marshall, September 1956.

MW-21: Pattern in the vertical of snow generation, by R.H. Douglas, K.L.S. Gunn and J.S. Marshall, July 1956.

MW-22: Precipitation mechanisms in convective clouds, by T.W.R. East, January 1956.

MW-23: Measurement and calculation of fluctuations in radar echoes from snow, by Walter Hitschfeld and A.S. Dennis, July 1956.

MW-24: The plan pattern of snow echoes at the generating level, by M.P. Langleben, February 1956.

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MW-28: Electronic constant altitude plan position indicator for a weather radar, by T.W.R. East, November 1958.

MW-29: The motion and erosion of convective storms in severe vertical wind shear, by Walter Hitschfeld, July 1959.

MW-30: Alberta hail, 1958, and related studies. Parts I and II by R.H. Douglas, Part III by R.H.D. Barklie and N.R. Gokhale, July 1959.

MW-31: The quantitative display of radar weather patterns on a scale of grey, by T.H. Legg, June 1960.

MW-32: Weather-radar attenuation estimates from raingauge statistics, by P.M. Hamilton and J.S. Marshall, January 1961.

MW-33: Improvements in weather-radar grey scale, by F.T. Barath, July 1961.

MW-34: Interim account of hail studies - November 1960, by R.H. Douglas, J.S. Marshall and R.H.D. Barklie. Reprinted in April 1962.

MW-35: Alberta Hail Studies, 1961, by A.E. Carte, R.H. Douglas, C. East, K.L.S. Gunn, Walter Hitschfeld, J.S. Marshall, E.J. Stansbury, December 1961.

MW-36: Alberta Hail Studies, 1962/63, by A.E. Carte, R.H. Douglas, R.C. Srivastava and G.N. Williams, August 1963.

MW-37: Precipitation profiles for the total radar coverage, by P.M. Hamilton, September 1964.

MW-38: Two studies of convection, by R.C. Srivastava and C.D. Henry, October 1964.

MW-39: Interpretation of the fluctuating echo from randomly distributed scatterers: Part 3, by Paul L. Smith, Jr., December 1964.

MW-40: Facsimile and areal integration for weather radar, Vols. I and II, by Marceli Wein, April 1965.

MW-41: Time-dependent characteristics of the heterogeneous nucleation of ice, by Gabor Vali and E.J. Stansbury, April 1965.

MW-42: Alberta Hail Studies, 1964, by J. Derome, R.H. Douglas, W. Hitschfeld, M. Stauder, July 1965.

MW-43: Attenuation of a parallel beam of light, particularly by snow, by Olav Lillesaeter, April 1965.

MW-44: Measurements on new-fallen snow, by K.L.S. Gunn, August 1965.

MW-45: Measurements on falling snow, by K.L.S. Gunn and M. Wein (to be published December 1965).

MW-46: Experiments on the nucleation of ice, 1961-63, by G. Vali and E.J. Stansbury, August 1965.

MW-47: Number in reserve for the future.

MW-48: Part I of Air Transport Association Report "Parameters for airborne weather radar" by J.S. Marshall, C.D. Holtz and Marianne Weiss will be issued with this number, December 1965.

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