

第10章 結び—将来の展望・課題*

わが国においては気象庁以外においても、気象レーダの高度利用が進められている。たとえば電波研究所の鹿島支所では、衛星マイクロ波通信の研究のためドップラーレーダによる雨域の解析がなされ、類似のものが国際電気研究所により山口衛星通信所（山口県）及び高萩通信所（茨城県）において実施されている。また建設省では豪雪地帯でレーダ観測の利用が進んでいる。電力会社も山岳地帯の雨観測や雷監視にレーダを用いている。

このようにレーダ利用の高度化に対し、社会的要求が高まっている現在、我々はさらにこの改善と利用方法の拡大を進めるべきである。そこで将来の気象業務あるいは研究のため、さらに開発研究を進めるべきものを以下に列挙する。

(1) 装置を含む観測方法の改善

① ドップラー強風測定の改善

周知のようにパルス繰返し周期による制約のため、風速のドップラー測定ではある風速以上は単純には不可能である。もちろん周辺の風速分布状況から、この制約を越えて風速を決定することが出来る。これを常に自動的に決定する方法を確立すべきである。

② エコートップ高度の測定精度の改善

アンテナのサイドローブのため積乱雲等の雲頂高度の決定には誤差が大きい。この問題を解決することは以前からの課題である。対流活動を明確に示すためにも、また航空気象上からも強く希望されているものである。

③ 局所的強い風シア検出方法の改善

これは微気象的にも航空気象上からもきわめて重要なものである。後述の(2)(3)で強く要求されるものとなる。

④ エコー処理における並列の複数マイコン利用の開発

ドップラー処理を含むエコーデジタル処理は、多くの場合大型電算機に依存している。このままではデータ処理高度化は限られた施設だけのものとなる。これを改善するには、複数のマイコンの並列運転による処理が考えられよう。このため従来の大型電算機のパイプライン処理法ではなく、複数の安価な電算機を利用する並列処理法を開発すべきである。

メモリーストレージにもビデオテープレコーダ利用のテープが使用されるべきである。

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⑤ VHF 帯ドップラーレーダによる風鉛直分布等の測定法の改善

1965 年前後から VHF ドップラーレーダによる風測定が試みられてきた。電波反射体は気温の不
均一の乱れである。最近の 10 年間電離層、中層大気等の高層大気探測のため、京大の Mu レーダの
ような超大型の VHF レーダが少くとも 10 数箇所以上設置されるにいたった。これらのレーダで
は、いわば副産物的にきわめて容易に（晴雨に抱らず）風速測定が可能であることを示している。
われわれは当面超高層は対象とする必要はなく、精々下部成層圏までで良いと思われる。従って超
大型 VHF レーダでなくてよい。問題は雑音電波の影響除去にあると思われるが、パッシブ的な除去
法だけでなく、アクティブ的な除去法も併用する価値がある。

なおこのレーダは圏界面の検出も可能であるが、実用的な方法を確立すべきである。

(2) 気象解析

① 台 風

継続して研究すべきことはいうまでもない。台風が日本近傍にある場合と上陸後の場合に一応は
限られるが、湿潤気流の流入の構造の精密な解析は、台風の変質、進路等に非常に有効な資料を与
えると思われる。台風による集中豪雨の予測の発展には、欠くことの出来ないステップであろう。

② 集中豪雨雪

台風に伴うものは上記の通りであるが、停滞降雨帯性あるいは地形要因性等について、気流系の
詳細な観測、解析はドップラーレーダによって始めて行われる。この詳細な解析こそが集中豪雨雪
の予報への道を開くと思われる。

③ 雷雨、雹、竜巻、突風

これらは米国、英国で大きな進展を見ているが、すべてドップラーレーダの利用の結果である。
我が国においても一般的な予警報のためだけでなく、航空気象その他特殊の分野の要望に応えるよ
う、研究を進めるべきである。

④ 航空気象

今までの項目内で述べたことのほかに、晴天乱流がある。これには(1)⑤で述べた VHF レーダが最
も有効と考えられる。空港周辺の乱気流に対しては、VHF レーダを試みた例を聞かないが、周囲環
境のいわゆる雑音に対して、基礎から実験的に対策を研究すべきであろう。しかし空港からある方
向で離れた地点で監視することが、その空港にとって有用であるならば、そこで VHF レーダの利用
を考えることは、晴雨に関係しないという点で非常に興味あるものである。

空港周辺の乱気流及び風シアの観測について、現時点で実用化されているものは、ドップラーソー
ダ（音響レーダ）とマイクロ波ドップラーレーダの併用である。前者は非降雨時及び弱雨時（すな
わち強雨時を除く場合）に用いられ、後者は降雨時に用いられて相補的である。これらの利用は米
国、欧州では盛んであるが、まだ最近のことである。効果的な利用方法の確立は今後の問題である

ので、わが国においてもこの方面の開発を進めるべきであろう。

⑤ 雲物理、境界層等の研究

雲物理ではふるくからレーダは利用されてきたが、今後も益々利用されることはいうまでもない。ここにこまかく述べる必要はないが、気象の人工調節の面などでは実用的にも必須の手段である。

境界層では山岳による晴天乱流の発生の観測などに用いられてきた。今後もこの種の研究と、本報告にも述べられているような境界層内の空気塊の移流・拡散の問題と大いに利用されるであろう。しかし、ドップラーソーダもこの種の研究に活用されていることも留意すべきである。

⑥ 海況観測

海の波浪観測にレーダを利用する研究は、気象レーダの利用開始とともに試みられてきた。現在ドップラーレーダによる観測が再び試みられてきたのは、一つには人工衛星搭載のマイクロ波散乱計による波浪観測の実験に伴って、現われてきたと考えられる。この衛星観測は今後の重要な課題であるので、開発の基礎として、海岸あるいは船舶のドップラーレーダによる解析を、より精密化することが望まれている。衛星波浪観測が実用的になった段階でも、衛星観測の常として、いくつかの基準測定箇所が必要であり、海岸（あるいは島）設置のレーダ観測が要求される。

以上不備な点を恐れるが、あえて述べた。将来多少でも役立つことを願って本章を終える。

Figure Captions

- Photo 2.1 Doppler PPI echo display, elevation 3.3°, range marker 20km, 09h 02m 23, June 1981.
- Photo 6.1 Example of PPI display showing horizontal distribution of Doppler velocity observed at 040626 JST, January 25, 1985.
- Photo 6.2 Example of REI display showing vertical cross-section of Doppler velocity observed at 034821 JST, January 25, 1985.
- Photo 7.1 Chaff echoes of X-band Doppler radar on 16 Oct 1984 at 12: 47: 59.
- Photo 7.2 Same as in Photo. 7. 1 except at 13: 08: 21.
- Photo 7.3 Same as in Photo. 7. 1 except on 18 Oct 1984 at 14: 02: 20.
- Photo 8.1 PPI display of Doppler velocity field showing angel echo motion at 175930 JST, October 3, 1985.
- Photo 8.2 PPI display of Doppler velocity field showing insect-like motion at 164230 JST, October 4, 1982.
- Photo 9.1 Sea clutter shown on PPI display. The photography above shows intensity, and the bottom one Doppler velocity. It shows the north-east wind.
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- Fig. 1. 1 Basic system of the block diagram of the orthogonal phase detector.
- Fig. 1. 2 Vector representation of Doppler radar return.
- Fig. 1. 3 Aliasing effect of Doppler frequency in pulsed radar system.
- Fig. 1. 4 Doppler spectra of precipitation echo. (Left) non-aliasing, (Right) with aliasing.
- Fig. 1. 5 Block diagram of the 5.7 cm wavelength Doppler radar.
- Fig. 1. 6 Block diagram of the pulse pair processor.
- Fig. 1. 7 Block diagram of the 3.1 cm wavelength Doppler radar.
- Table.1.1 The characteristics of the programming language.
- Fig. 2. 1 Geometry of scan for wind measurements by VAD technique.
- Fig. 2. 2 VAD pattern made by wind and particle's fall speed.
- Fig. 2. 3 VRD pattern accompanied by aliasing effect.
- Fig. 2. 4 VAD patterns with examples of actual results. (Left) no turbulence, (Middle) with turbulence, (Right) with non-uniformity of fall speed.
- Fig. 2. 5 Correction of VAD pattern accompanied with data discontinuity in azimuth direction. (Left) before correction, (Right) after correction.
- Fig. 2. 6 Height distribution of standard deviation for VAD pattern shown by elevation angle as parameter. 21h July 2, 1980.
- Fig. 2. 7 As in Fig. 2. 6 except for 09h July 9, 1980.
- Fig. 2. 8 Comparison of wind profiles between radar of several elevation angles and sonde. 21h July 2, 1980.
- Fig. 2. 9 Comparison of wind profiles between radar with elevation angle of 30° and sonde. 21h July 2, 1980.
- Fig. 2. 10 As in Fig. 2.8 except for 09h July 9, 1980.
- Fig. 2. 11 As in Fig. 2. 9 except for 09h July 9, 1980.
- Fig. 2. 12 Standard deviations of radar wind data for various elevation angles compared with sonde data in 1980.
- Fig. 2. 13 Relationship between correlation coefficient and error rate, 9h June 12, 1981.
- Fig. 2. 14 Height distribution of errors for VAD patterns shown by elevation angles as parameter. 09h

- June 12, 1981. (Left) correlation coefficient, (Right) standard deviation.
- Fig. 2. 15 Correction of data missing of VAD. (Left) before correction, (Right) after correction.
- Fig. 2. 16 Height profiles of correlation coefficient before and after correction of data missing of VAD. 09h June 12, 1981.
- Fig. 2. 17 Comparison of wind profiles between radar and sonde. The radar data at altitude higher than that shown by the arrow was obtained by correction of VAD data missing.
- Fig. 2. 18 As in Fig. 2. 9 except for 09h June 12, 1981.
- Fig. 2. 19 Geometry for observing the velocity of a raindrop V by two Doppler radars. V_1 and V_2 are Doppler velocities observed by Radar 1 and Radar 2, respectively. R_1 and R_2 are distance between raindrop and radar.
- Fig. 2. 20 Location of the Doppler radars. The observation domains are shaded.
- Fig. 3. 1 Track of Typhoon 8124 together with its central pressure.
- Fig. 3. 2 Synoptic charts at 500-hPa level and at sea level for 21 JST on October 22, 1981. Solid and dashed lines represent geopotential height ($\times 10$ m) (or sea level pressure, hPa) and temperature ($^{\circ}\text{C}$) (or equivalent potential temperature, K), respectively.
- Fig. 3. 3 Contour map of equivalent blackbody temperature observed by GMS for 2040 JST on October 22, 1981. Contours are at 20°C intervals. Light and heavy shadings are areas with temperatures below -60°C and -70°C , respectively. The hatched shading indicates the core of the rainstorm. The position of the center of Typhoon 8124 is also shown.
- Fig. 3. 4 Radar echo map observed by the Mt. Fuji radar and vertical profiles of potential temperature θ , equivalent potential temperature θ_e , and saturation equivalent potential temperature θ_e^* at 21 JST on October 22, 1981 at Sendai, Tsukuba, Hachijojima, Wajima, Hamamatsu, Shionomisaki and Chichijima. Wind profile is also shown. Full barb for wind is 5 ms^{-1} . In shaded areas radar reflectivity exceeded 32 dBZ. The solid circle indicates the effective position of the Hamamatsu upper-air sounding which was made about one hour later than the indicated time.
- Fig. 3. 5 Local map of the rainfall amount (mm) during the previous one hour, wind velocity, surface air temperature ($^{\circ}\text{C}$) and the position of convergence line at 18 JST on 22 October 1981. Light, heavy and solid shadings indicate areas with hourly rainfall amount of more than 8 mm, 16 mm and 32 mm, respectively. Surface air temperature is indicated only in the southeastern part of the Kanto district where the land is relatively low. The convergence line is indicated by a thick dotted line. The wind velocity at Mt. Tsukuba (876 m above sea level) is shown by a bold arrow.
- Fig. 3. 6 As in Fig. 3. 5, except for 21 JST.
- Fig. 3. 7 As in Fig. 3. 5, except for 24 JST. The axis of an elongated divergence area is indicated by a double line.
- Fig. 3. 8 Record of the rainfall intensity meter at Tsukuba.
- Fig. 3. 9 Relative positions of Tsukuba and the cross-sections (C_1 , C_2 and C_3) in Figs. 3. 10-3. 12 to the typhoon center. Circles indicate the cylinders in which the mass budget was calculated. Radar echoes observed by the Mt. Fuji radar is illustrated schematically.
- Fig. 3. 10 Mesoscale features of the rainstorm in the northern part of the rainstorm. (a) NW-SE vertical cross-section of reflectivity (dBZ) and Doppler velocity (ms^{-1}) (positive north-westward). Bold arrows on the abscissa indicate the position of the surface convergence line. Precipitation echo in the blank area on the northwestern side was contaminated with ground clutter. (b) Time-height section of reflectivity and vertical air velocity. The samples were

collected every 30 seconds. Solid lines in the lower part are isopleths for 4, 2, 0, and -2 ms^{-1} .
(c) Cylindrical representation of Doppler velocity and mean vertical velocity in the circular area and vertical profiles of horizontal divergence and vertical velocity.

- Fig. 3.11 As in Fig. 3.10, except for the middle part of the rainstorm.
- Fig. 3.12 As in Fig. 3.10, except for the southern part of the rainstorm.
- Fig. 3.13 Horizontal distribution of reflectivity at the 5-km and 2-km levels in the southern part of the rainstorm.
- Fig. 3.14 Schematic illustration of the rainstorm which occurred to the north of the center of Typhoon 8124 (Gay) in the transformation stage into an extratropical cyclone.
- Fig. 3.15 Track of Typhoon 8305. The location of the storm center and the central pressure are indicated every 24 hours.
- Fig. 3.16 Weather charts at the surface (a) and at 500 hPa (b) at 0900 JST 17 August 1983.
- Fig. 3.17 Distribution of radar echoes observed by the Mt. Fuji radar at 0700 JST 17 August 1983. Arrows indicate the location of the rainband.
- Fig. 3.18 PPI pattern of reflectivity observed by the Tsukuba 5-cm Doppler radar at 0710 JST 17 August 1983. Elevation angle is 0.9° . Arrows indicate the rainband under discussion. Contours start at 20 dBZ with a 5 dB increment. Areas with reflectivity greater than 30 dBZ are shaded.
- Fig. 3.19 Hodograph of mean winds deduced from the dual Doppler radar observation. The mean motion of echoes in the rainband $\mathbf{V_e}$, the storm center motion $\mathbf{V_c}$, and the echo motion relative to the storm center $\mathbf{V_{ec}}$ are also shown.
- Fig. 3.20 Vertical profiles of potential temperature θ , equivalent potential temperature θ_e , and saturation equivalent potential temperature θ_e^* observed at Tsukuba at 0830 JST 17 August 1983.
- Fig. 3.21 Horizontal sections of reflectivity and horizontal air-flow relative to echoes in the rainband at 0.8 km level (a), 1.5 km (b), 2.5 km (c), 3.6 km (d), 4.5 km (e), and 6.1 km (f) at 0741 JST 17 August 1983. The increment of reflectivity contours is 5 dB. Areas with reflectivity greater than 30 dBZ are shaded. Mean wind at each level is indicated at the bottom of the figure. Solid squares indicate the locations of Doppler radars.
- Fig. 3.22 The location of the composite cross-sections of Fig. 3.23~Fig. 3.28. The composite cross-sections are made in the area enclosed with the solid line A-A'-B'-B-A. Stippled shading indicates the area with reflectivity greater than 30 dBZ at 2.5 km level. The dashed line C-C' indicates the location of the REI scan by the 3-cm Doppler radar as shown in Fig. 3.29. The observation domain is divided into three parts, the outer side, the rainband, and the inner side.
- Fig. 3.23 Composite vertical cross-section of reflectivity (Z_e) in the radial direction from the typhoon center. The cross-section is made from the data shown in Fig. 3.21. The composite area is shown in Fig. 3.22. The contour interval is 5 dB and areas with reflectivity greater than 30 dBZ are shaded. Horizontal axis is indicated by the radial distance from the storm center.
- Fig. 3.24 As in Fig. 3.23 except for the radial component of relative horizontal wind to the echoes in the rainband (V_r'). The contour interval is 1 m/s. Positive areas are shaded. The dashed line shows the contour of 30 dBZ.
- Fig. 3.25 As in Fig. 3.23 except for the tangential component of relative horizontal wind (V_θ').
- Fig. 3.26 As in Fig. 3.23 except for composite divergence. The contour interval is $2 \times 10^{-4} \text{ s}^{-1}$. Positive areas are shaded.

- Fig. 3.27 As in Fig. 3.23 except for divergence deduced from V_r' .
- Fig. 3.28 As in Fig. 3.23 except for composite vertical velocity (W). The contour interval is 0.5 m/s. Positive areas are shaded.
- Fig. 3.29 REI pattern of reflectivity (a), and Doppler velocity (b) observed by the 3-cm Doppler radar in the direction of 20 at 0737 JST 17 August 1983. The location of this section is indicated in Fig. 3.22. The contour interval is 5 dB and areas with reflectivity greater than 30 dBZ are shaded. Note that the vertical exaggeration is different from Fig. 3.23~Fig. 3.28. The dashed line in (b) indicates the contour of 30 dBZ.
- Fig. 3.30 Horizontal sections of vertical velocity at 3.6 km level. Solid lines show contours of updraft starting at 1 m/s with a 2 m/s increment, and dashed lines show contours of downdraft.
- Fig. 3.31 Track of Typhoon 8514. The location of the storm center is indicated every 6 hours and the center pressure is indicated every 24 hours.
- Fig. 3.32 Weather chart at sea level for 21 JST on August 30 1985.
- Fig. 3.33 Weather chart at 500-hPa level for 21 JST on August 30 1985. Solid and dashed lines represent geopotential height ($\times 10$ m) and temperature ($^{\circ}\text{C}$).
- Fig. 3.34 Radarecho map observed by the Tsukuba radar on August 30-31, 1985. In hatched areas radar reflectivity exceeded 30 dBZ.
- Fig. 3.35 Record of the rainfall the intensity meter at Tsukuba.
- Fig. 3.36 Time evolution of the rainband observed by the Tsukuba radar. Areas in which radar reflectivity exceeded 35 dBZ are shown. In solid shading areas, radar reflectivity exceeded 40 dBZ.
- Fig. 3.37 Doppler-derived horizontal wind and radar reflectivity. Solid lines are isopleths of radar reflectivity at 2.5dB intervals. In hatched areas, radar reflectivity exceed 30 dBZ.
- Fig. 3.38 Horizontal sections of divergence (a) at 1 km (b) at 3 km and (c) at 5 km. Solid and dashed lines are isopleths of convergence and divergence starting at $\pm 5 \times 10^{-4} \text{s}^{-1}$ with $1 \times 10^{-3} \text{s}^{-1}$ increment.
- Fig. 3.39 Locaton of the composite cross-sections of Fig. 3.40-Fig. 3.44. Stippled shading indicates the area in which radar reflectivity exceeds more than 30 dBZ at 3 km level.
- Fig. 3.40 Composite vertical cross-section of reflectivity (Z_e) in radial direction from the typhoon center. Isopleths are 2.5 dB intervals and areas with reflectivity greater than 30 dBZ are shaded.
- Fig. 3.41 As in Fig. 3.40 except for relative wind to the rainband (V_r). The isopleths are 1 m/s intervals. The dashed line is isopleth of 30 dBZ. Positive value indicates the flow from the storm center.
- Fig. 3.42 As in Fig. 3.40 except for the tangential component of relative horizontal wind (V_{θ}). Positive value indicctes the flow to west.
- Fig. 3.43 As in Fig. 3.40 except for composite divergence. The isopleths are at $3 \times 10^{-4} \text{s}^{-1}$ intervals. Positive areas are shaded.
- Fig. 3.44 As in Fig. 3.40 except for composite vertical velocity (W). The isopleths are at 1 m/s intervals. Positive areas are shaded.
- Fig. 4.1 Chart of surface pressure at 21JST on 25 September 1981. Isoplethe of surface pressure are at intervals of 4hPa.
- Fig. 4.2 As in Fig. 4.1, except for the chart of 850hPa. Solid lines indicate contours at intervals of 60m. Dashed lines are isoplths of temperature at intervals of 3°C .
- Fig. 4.3 Vertical profiles of potential temperature θ , equivalent potential temperature θ_e , and

saturation equivalent potential temperature θ_e^* at Tateno at 2030JST on 25 September 1981.

- Fig. 4. 4 Radar echoes by the Mt. Fuji radar at 21 and 23JST on 25 September 1981. Stippled and solid shading indicate echoes the intensity of which is equivalent to precipitation intensity exceeding 4 mmhr^{-1} and 16 mmhr^{-1} , respectively.
- Fig. 4. 5 Distribution of precipitation amount in the previous one hour observed by the Automated Meteorological Data Acquisition System from 23JST on 25 September 1981 to 02JST on 26 September. Dashed lines are isopleths of precipitation amount of 5 mmhr^{-1} , and solid lines are isopleths of precipitation amount starting at 10 mmhr^{-1} with 10 mmhr^{-1} increment.
- Fig. 4. 6 Time sequence of radar echoes by Tsukuba radar the intensity of which exceeds 35dBZ from 2113JST on 25 September 1981 to 0223JST on 26 September. The cross indicates the position of Tsukuba radar.
- Fig. 4. 7 Reflectivity and Doppler velocity of the 2-km level at 2349JST on 25 September 1981. The isopleths of reflectivity are at 5 dB intervals and regions with reflectivity exceeding 35dBZ are shaded. The isopleths of Doppler velocity start at $\pm 1 \text{ m/s}$ and its intervals are 2m/s. Regions with positive Doppler velocity are shaded.
- Fig. 4. 8 As in Fig. 4.7 except for at 0058JST on 26 September 1981. The solid line which extends to C indicates the direction of the vertical cross section in Fig. 4.12.
- Fig. 4. 9 As in Fig. 4.7 except for Doppler velocity at 3, 4, 5-km level at 0058JST on 26 September.
- Fig. 4. 10 As in Fig. 4.7 except for 0228JST on 26 September.
- Fig. 4. 11 As in Fig. 4.7 except for Doppler velocity at 3, 4-km level at 0228JST on 26 September.
- Fig. 4. 12 Vertical cross-section of Doppler velocity (a), and reflectivity (b), in the direction 175.8° . The isopleths of Doppler velocity start at -1 m/s and its intervals are 4m/s. Regions with Doppler velocity below -15 m/s are stippled. The isopleths of reflectivity are at 5dB intervals and regions with reflectivity exceeding 35 dBZ are stippled. Dashed lines indicate noise level of reflectivity.
- Fig. 4. 13 As in Fig. 4.7 except for at 2237JST on 25 September.
- Fig. 4. 14 Distribution of wind velocity observed by the Automated Meteorological Data Acquisition System from 23JST on 25 September 1981 to 02JST on 26 September. Thin wind symbols indicate 1m/s and thick ones indicate 5m/s.
- Fig. 4. 15 Map of surface temperature ($^\circ\text{C}$). L, X indicate the position of the cyclone and the center of cyclonic circulation. Surface air temperature is indicated only where the height is relatively low.
- Fig. 4. 16 Surface chart for 03JST on 28 January 1985. Isobars are at 4hPa intervals.
- Fig. 4. 17 Cloud photograph of GMS-III infrared imagery at 03JST on 28 January 1985.
- Fig. 4. 18 Time sequence of composite radar echoes by the Fukui and Niigata radars from 03JST to 06JST on 28 January 1985.
- Fig. 4. 19 Time sequence of radar echoes around the observation area of the Doppler radar at Kanazawa by the Fukui radar from 0330JST to 0700JST on 28 January. Elevation angle is 1.0° . The observation domain by Doppler radar is enclosed by a circle. Isopleths indicate reflectivity converted into precipitation intensity at 0.25 mmhr^{-1} intervals. The areas higher than 1,000m above sea level are shaded (0330JST and 0700JST). The location of cross sections in Fig. 4.21 is indicated by a solid line.
- Fig. 4. 20 Vertical distributions of potential temperature θ , equivalent potential temperature θ_e and saturation equivalent potential temperature θ_e^* before the passage of the cold front

- (0230JST) and after that (0830JST). Vertical distribution of winds is also shown.
- Fig. 4. 21 Vertical cross-sections of reflectivity (a) and Doppler velocity (b) nearly perpendicular to the orientation of the cold-frontal rainband. Time advances from up to down. Isopleths of reflectivity are at 5dB intervals. Regions with reflectivity exceeding 30dBZe are shaded. Isopleths of Doppler velocity are at 2ms^{-1} intervals. Regions with positive Doppler velocity are shaded. Bold arrow on the abscissa indicates location of convergence area.
- Fig. 4. 22 Time variation of meteorological elements at the Doppler radar site from 04JST to 07JST on 28 January 1985.
- Fig. 5. 1 Vertical profiles of potential temperature θ , equivalent potential temperature θ_e and saturation equivalent potential temperature θ^*_e and hodograph observed at Tateno 0830JST 27 JULY 1983.
- Fig. 5. 2 Time sequence of the line echo observed by Tokyo radar. (1400-1600JST 27 July 1983)
- Fig. 5. 3 Distribution of horizontal winds V , and reflectivity Z_e (1449, 1503 and 1524 JST ; 1.0,3.0 and 5.0 km in height). The mean wind at each level is shown at the right-hand bottom of the figure, and the scale of wind vector at the left-hand bottom. Contours of Z_e are drawn from 15 dBZ at intervals of 5 dB. Areas exceeding 40dBZ are shaded. Small squares indicate the location of 3 and 5cm Doppler radars.
- Fig. 5. 4 As in Fig. 5-3 except for the wind subtracted from the mean wind at each level V' .
- Fig. 5. 5 Distribution of surface temperature determined from AMeDAS at 1500JST 27 July 1983. The location of the line echo is shown by stippling.
- Fig. 5. 6 Distribution of vertical velocity w and reflectivity factor Z_e . The times and levels are the same as in Fig. 5-3 Solid lines show updraft, and dashed lines downdraft. Contours of w are drawn from $\pm 1.0\text{m/s}$ at intervals of 5 m/s. Contours of Z_e are 15 and 40 dBZ, and areas exceeding 40 dBZ are shaded.
- Fig. 5. 7 As in Fig.5-1 except for at Tateno 0830JST 3 August 1984.
- Fig. 5. 8 Time sequence of the thunderstorm echo observed by Tokyo radar(1643-1800JST 3 August 1984). Dashed lines show the location of echoes at the times below.
- Fig. 5. 9 Distribution of horizontal wind relative to the moving thunderstorm V_s , and reflectivity Z_e (1719JST 3 August 1984 ; 1.0,2.5,4.0,5.5 and 7.0km in height). The movement of thethunderstorm is shown at the right-hand bottom of the figures. Contours Z_e are drawn from 15 dBZ at intervals of 5 dB. Areas exceeding 45 dBZ are shaded.
- Fig. 5. 10 Distribution of vertical velocity w , and reflectivity Z_e . The time and levels are the same as in Fig. 5-9. Solid lines show updraft and dashed lines downdraft. Contours of w are drawn from $\pm 3\text{m/s}$ at intervals of 5 m/s. Contours of Z_e are 15 and 45 dBZ, and areas exceeding 45 dBZ are shaded.
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- Fig. 6. 7 Rader reflectivity field (right ; oblique line area is $>30\text{dBZ}$) and Doppler velocity field (left ;

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- Fig. 6. 12 Same as in Fig. 6.10 except for the time.
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Composite vertical cross-section of radar reflectivity (Z_e), Doppler velocity (U , oblique line area is positive velocity) and vertical current (W , oblique line area is upward current area) from 1458JST to 1523JST on 27 January 1984.
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- Fig. 6. 16 Two-hourly precipitation amount from 1700JST to 1900JST on 25 January 1984. Isopleths indicate 1, 2, 4 and 8mm. The dotted line is an isopleth of 6mm. The dashed lines are contours at intervals of 500m. Regions higher than 1,000m are shaded.
- Fig. 6. 17 Mean vertical profiles of potential temperature θ , equivalent potential temperature θ_e and saturation equivalent potential temperature θ_e^* at 15 and 21JST on 25 January 1984 at Kanazawa.
- Fig. 6. 18 Hodographs of mean wind around Kanazawa at 1705JST and 1837JST on 25 January 1984. Mean wind was derived with the modified VAD method on the circular with radius of 20km.
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- Fig. 6. 21 Vertical cross-sections of snowbands A and B observed by Doppler radar from 1740JST to 1825JST on 25 January 1984. (a) Reflectivity (dBZ_e). Regions with reflectivity exceeding 30dBZ_e are shaded. (b) Horizontal velocity relative to the cloud systems (positive rightward) (ms^{-1}). Regions with positive velocity are shaded.
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- Fig. 6. 29 Composite radar echo by Matsue and Fukui radars at 21JST on 29 January 1985. Solid shading indicates echoes with intensity equivalent to precipitation intensity exceeding 4mmhr^{-1} .
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- Fig. 6. 33 Vertical cross-sections of reflectivity and Doppler velocity in the direction $290^\circ\text{--}110^\circ$. Solid shadings indicate regions with Doppler velocity less than -10ms^{-1} .
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- Fig. 7. 1 Schematic diagram of chaff released from the airplane and velocity observations by two Doppler radars.
- Fig. 7. 2 Distribution of the falling terminal velocities of C-band GL chaff needles.
- Fig. 7. 3 Diagram of radar beam paths for elevation angles.
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- Fig. 7. 5 Schematic diagram of courses of the airplane (solid line) and chaff-releasing points (open circles). a) Wind field observation by chaff. b) Observation of chaff diffusion.
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Fig. 8.6 Radar cross-sections of insects as a function of the radar wavelength.

Fig. 9.1 Locations of observational facilities, A: transportable X band Doppler radar, B: Chosi observatory, C: observational facilities maintained by the Physical Meteorology Research Division of the Meteorological Research Institute, D: C band Doppler radar of the Radio Research Laboratory, E: ultra-sonic wave gauge of the Port and Harbour Research Institute.

Fig. 9.2 Wind direction and velocity observed at Hazaki during observational periods, (a) from 20 to 22, Nov., 1984, (b) from 5 to 8, Dec., 1984.

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Fig. 9.4 Comparisons of meteorological data and radar data. (a) wind velocity and intensity (b) wind velocity and doppler velocity (c) wave height and intensity (d) wave height and Doppler velocity.

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Fig. 9.6 Spectrum of intensity shown in Fig. 9.5.

Fig. 9.7 Spectrum of wave height at Kashima Harbour on 20 November.

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