A Case Study on Hail Detection in Thunderstorms as an Application of Polarimetric Radar*

*Polarimetric Radar = Dual Polarization Radar

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This survey has been made with Dr. Nagumo of JMA as a visiting research of the JMA Meteorological Research Institute.

Contents

1. Hail

Hail, Graupel, Sleet and Snow

hail graupel sleet snow

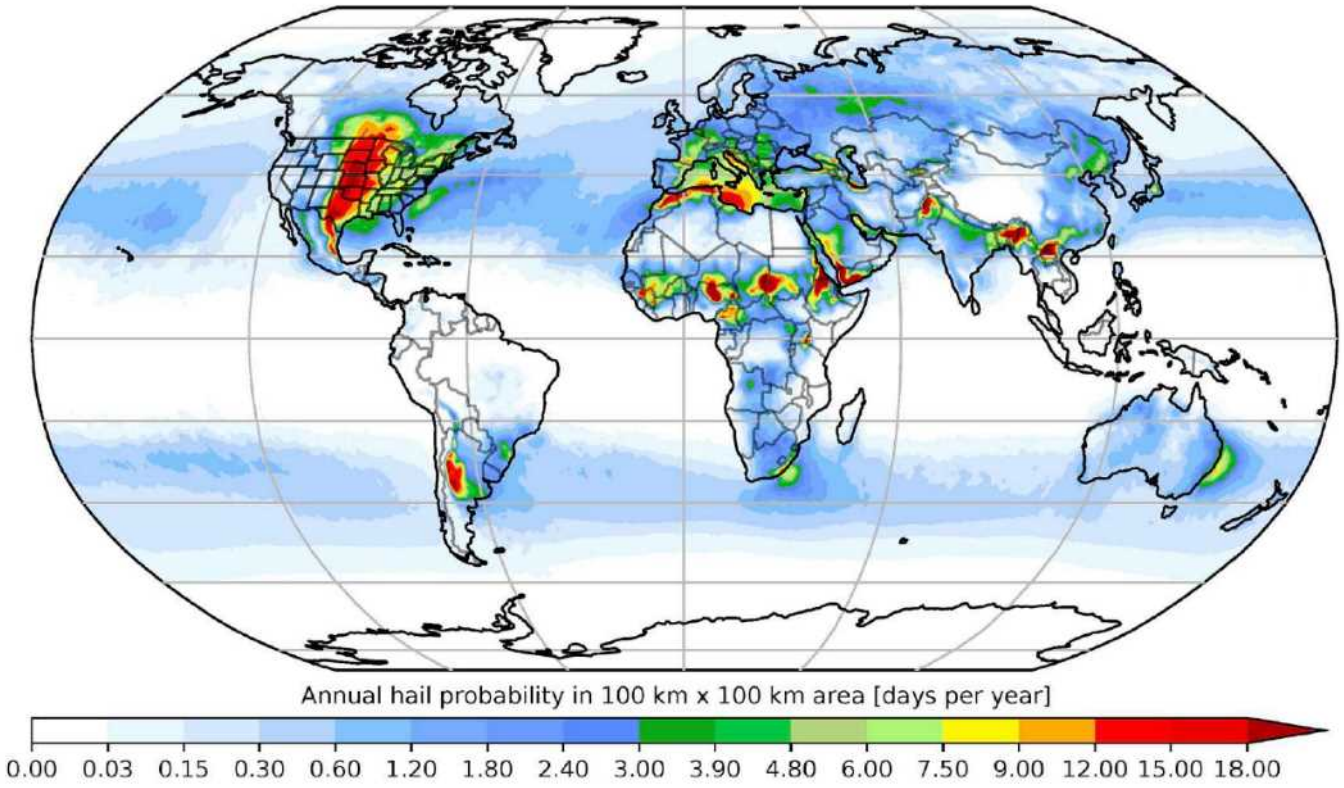
Severe Weather 101: Hail Basics (noaa.gov)

Hail. Precipitation of particles of ice (hailstones). These can be either transparent, or partly or completely opaque. They are usually spheroidal, conical or irregular in form, and generally 5−50 mm in diameter. The particles may fall from a cloud either separately or agglomerated in irregular lumps. Falls of hail always occur as showers. They are generally observed during heavy thunderstorms.

Guide to Instruments and Methods of Observation Volume III – Observing Systems 2021

Global annual average large hail* probability

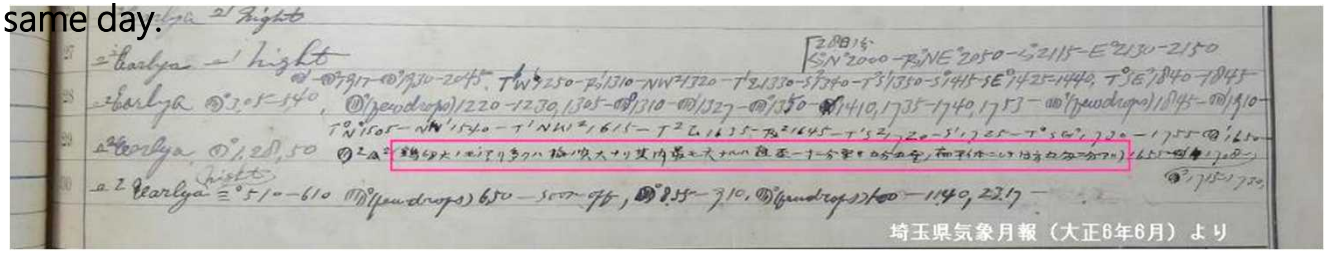
Prein and Holland (2018) *hail of diameter greater than 2.5 cm in diameter



The predictors include atmospheric instability, freezing level height, and 0–3 km wind shear and storm relative helicity. These variables are used to develop a hail algorithm, which provides the probabilities for large hail occurrence from regional to global scales and from daily to climate timescales.

Hail and Hail Damage in Japan

The Meteorological Summary of the Japan Meteorological Agency (JMA) reported that severe hailstones as large as chicken eggs were observed at the JMA Kumagaya Meteorological Office at 16:50 on 29 June 1917 and that at Nagai-mura, Saitama Prefecture, Japan, a priest of a Buddhism temple found a large hailstone of 29.5 cm in diameter on the same day.



熊谷地方気象台 (jma-net.go.jp)

A heavy hail damage was reported in the Chiba Prefecture, Japan on 24 May 2000.
130 people were injured and the total payment for vehicle and fire insurances cost 309 billion yen (200 million US

図1　雹の写真（千葉県佐倉市　稍山　昇氏提供）
降雹後約20分後に撮影されたもので，雹の中の構造が見える。中央のさつきの大きさは約6cmである。

図2　降雹後の様子（茨城県利根町提供）
車の後輪が隠れるほど道路一面に雹が積もっている。

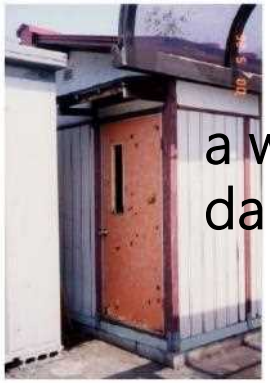


図8　物置扉の被害（我孫子市内）
木製の扉に無数の穴が開いている。中には裏側の板も打ち抜いて貫通しているものもある。

a wooden door damaged by hail

奥田・伊藤 2000

降雹被害.PDF (giroj.or.jp)

General Insurance Rating Organization of Japan

2. Questionnaire on Hail Damage and Hail Information

■ Questionnaire on Hail Damage and Hail Information in Your Country

Please put checks to the following items.

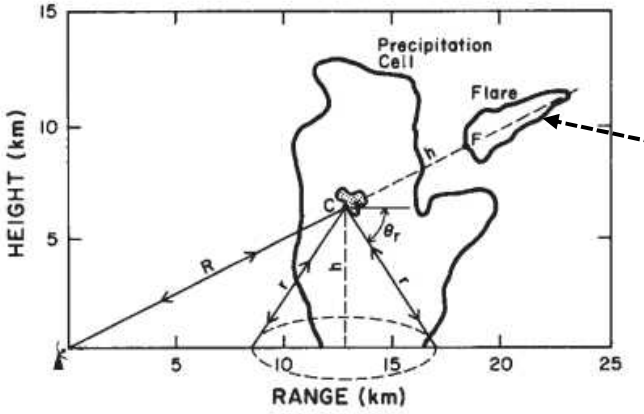
	Hail damage in your country	Current Information on hail issued from your weather services	Interest in hail detection/nowcasting with radars
Bangladesh	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Burnie	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Cambodia	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Indonesia	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Lao PDR	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Malaysia	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Myanmar	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Philippines	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Thailand	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Vietnam	☐None/slight ☐Moderate ☐Serious	☐None ☐Outlook ☐Advisory	☐None ☐Slight ☐Much
Japan	☐None/slight ☑Moderate ☐Serious	☐None ☑Outlook ☑Advisory	☐None ☑Slight ☐Much
Comment			

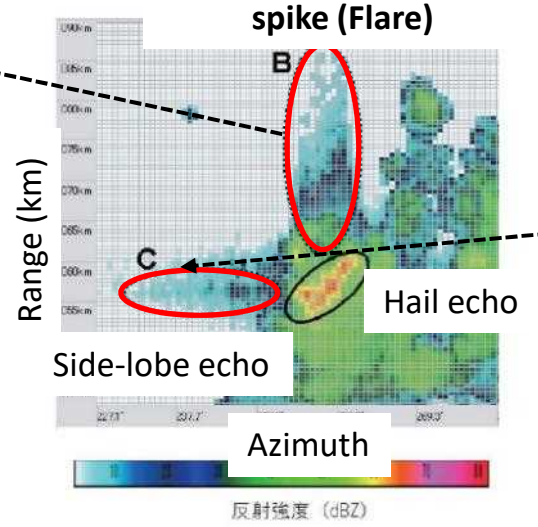
3. Hail Detection Methods

■ Legacy Hail Detection Methods 1: Pattern recognition

1. TBSS: Three-body scatter spike

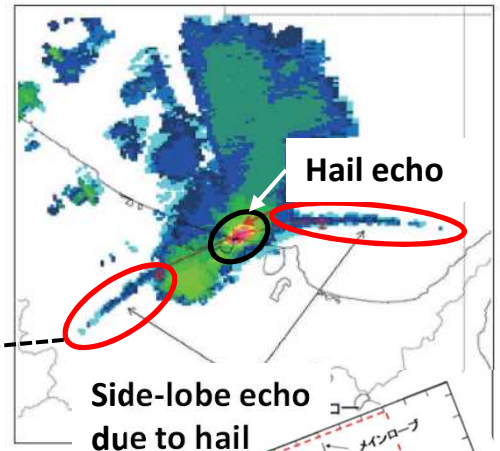
(Zrnic 1987; Wilson and Reum 1988)

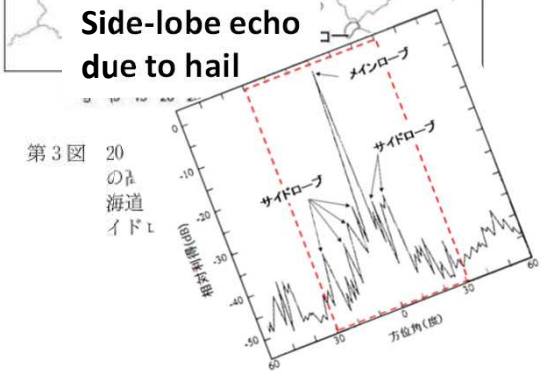




第２図　2006年７月15日に東京都多摩地区に出現した積乱雲にともない，12時50分に東京レーダーの仰角4.8度の反射強度データに現れた雹エコー（A），TBSS（B），サイドローブエコー（C）．横軸はアンテナの方位角，縦軸はレーダーからの距離．

2. Side-lobe echo due to hail

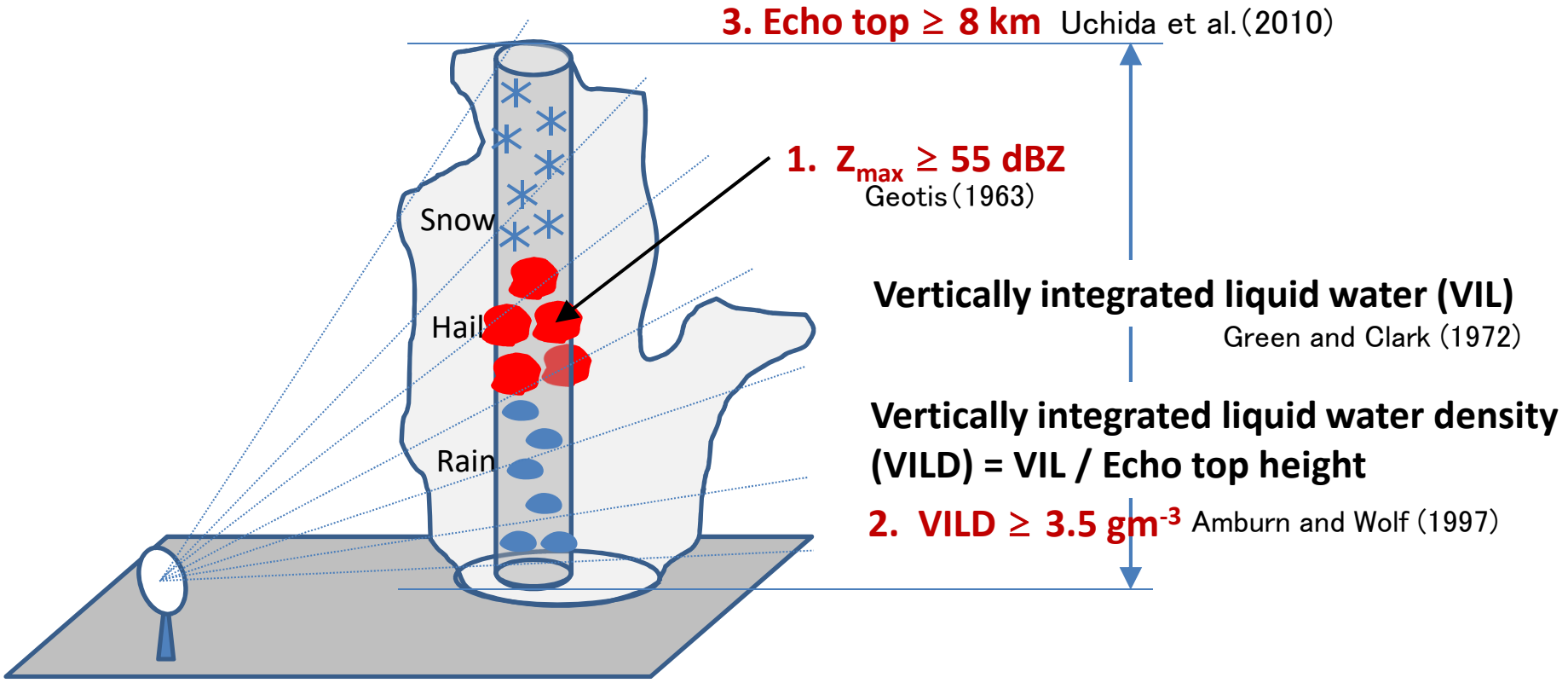




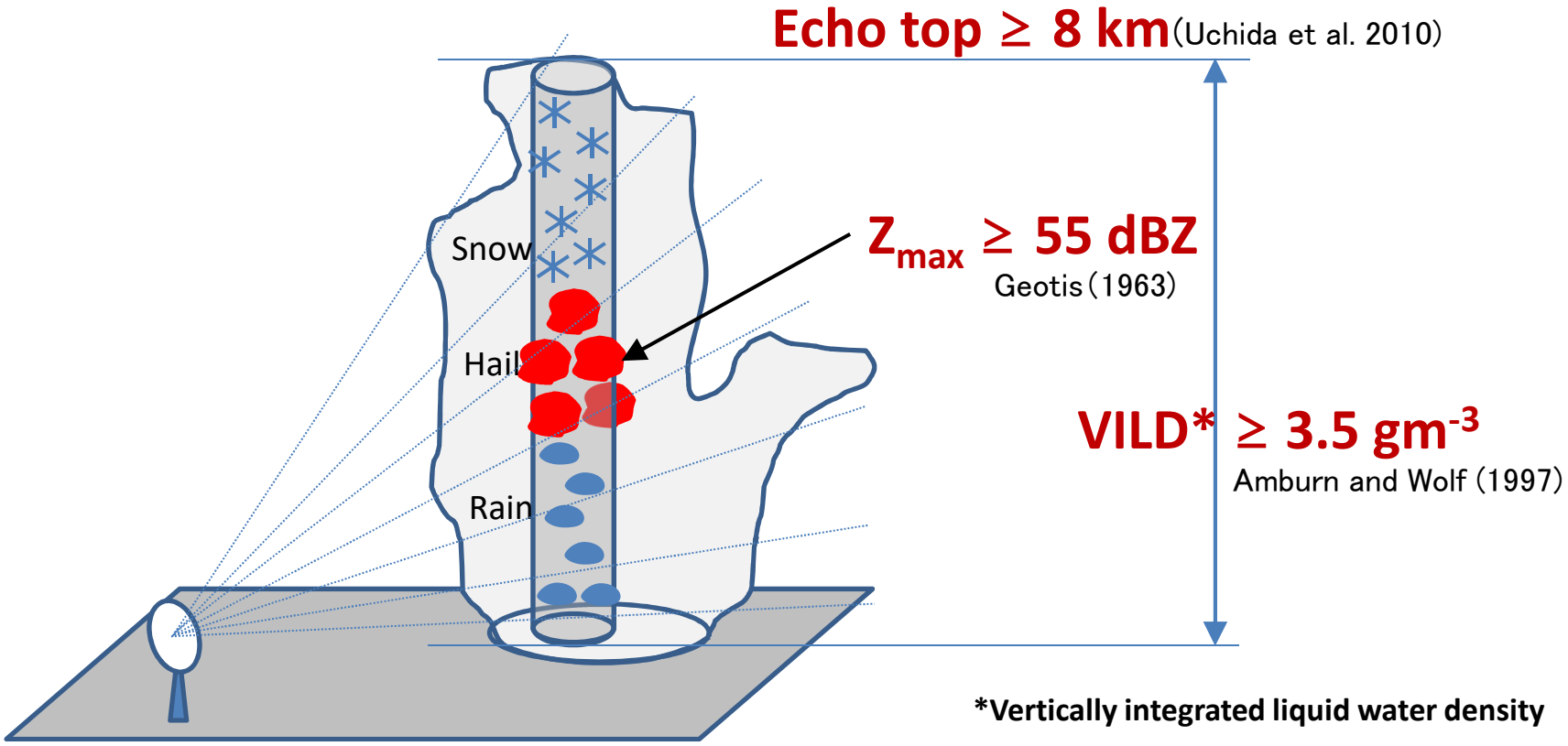
第３図　20
のレ
海道
イドレ

(Uchida et al. 2010)

■ Legacy Hail Detection Methods 2:
Criteria of hail occurrence possibility based on 3-D radar data

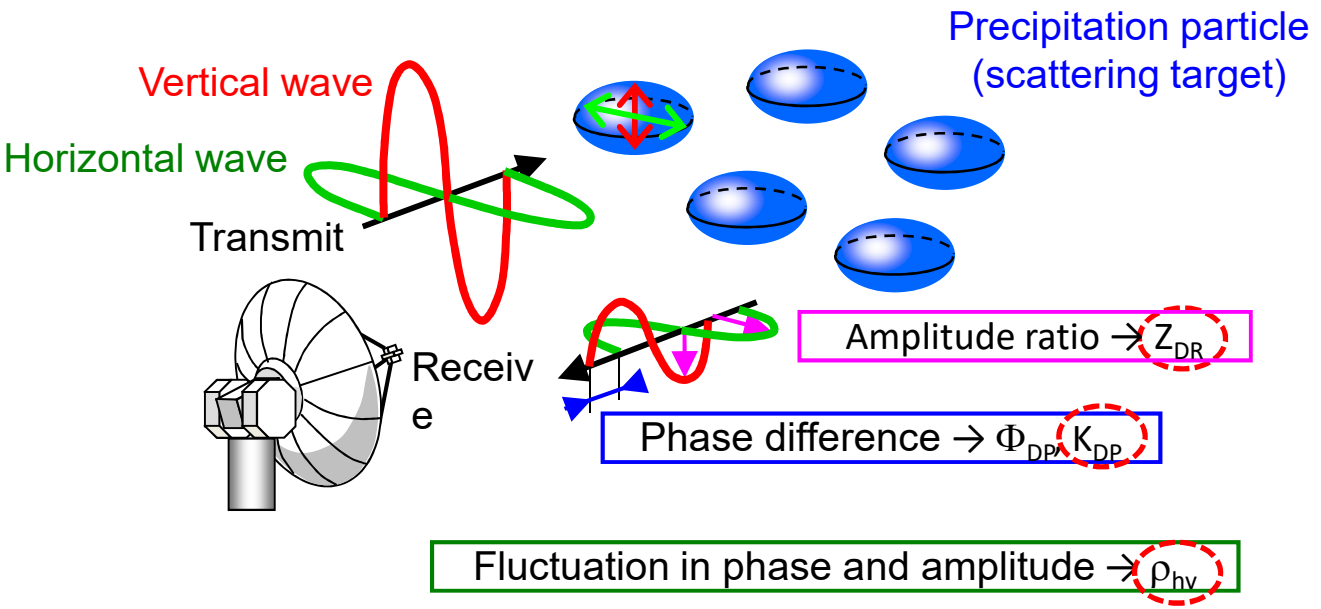


■ Legacy Hail Detection Methods 2:
Index of hail occurrence possibility based on 3-D reflectivity data



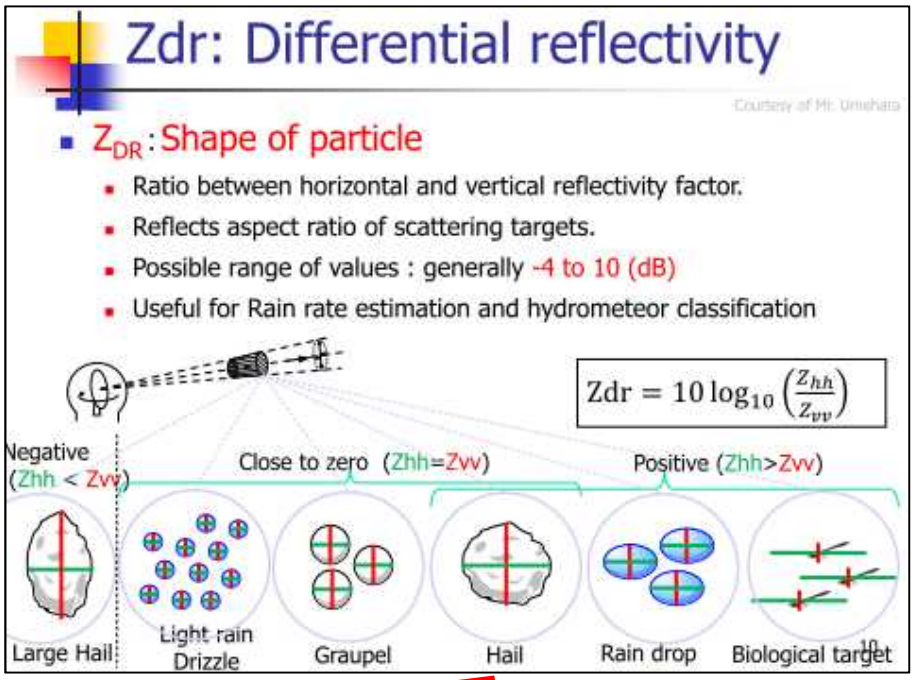
Precipitation particles and polarimetric parameters

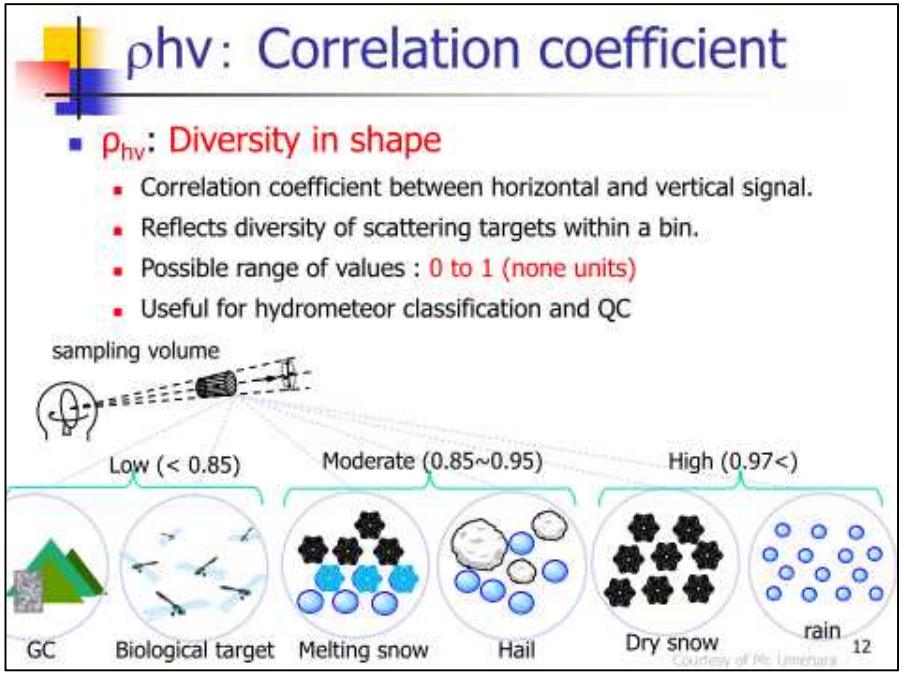
Yamauchi（2023）



Precipitation particles and polarimetric parameters

Yamauchi (2018 WMO/ASEAN Radar Workshop)





Precipitation particles and polarimetric parameters

Fabry (2015 Radar Meteorology)

Z_{DR} : Differential Reflectivity

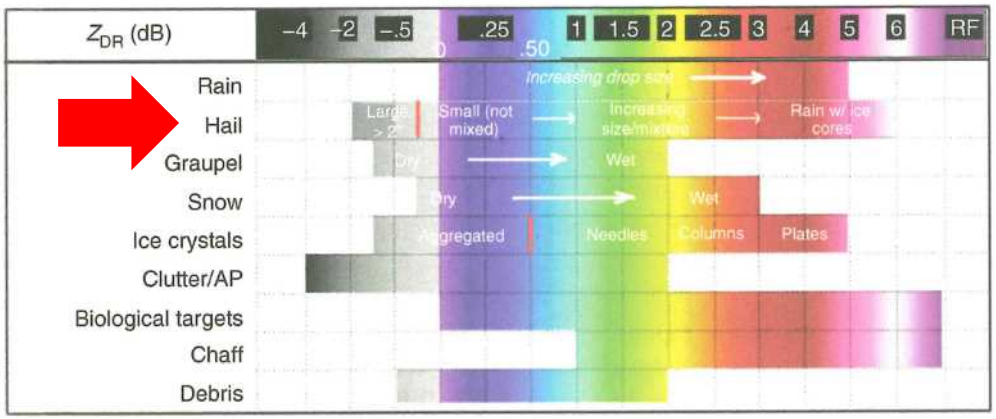


Chart of typical values of Z_{dr} for different types of targets. The colors correspond to the scale used on WSR-88D radar displays for Z_{dr}, while for each type of target, the range of colors represent the range of expected values. For hail, 2" corresponds to 5 cm. Image courtesy of the NOAA Weather Decision Training Branch (WDTB).

ρ_{hv} : Correlation Coefficient

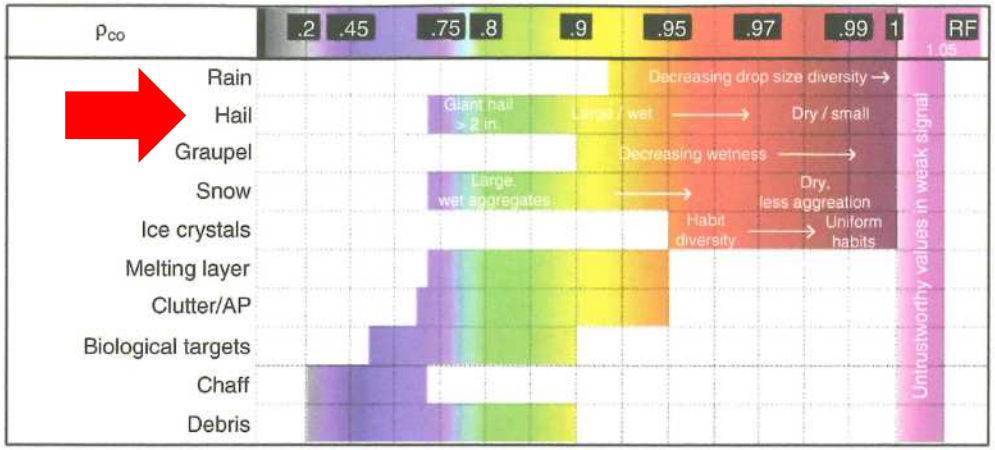
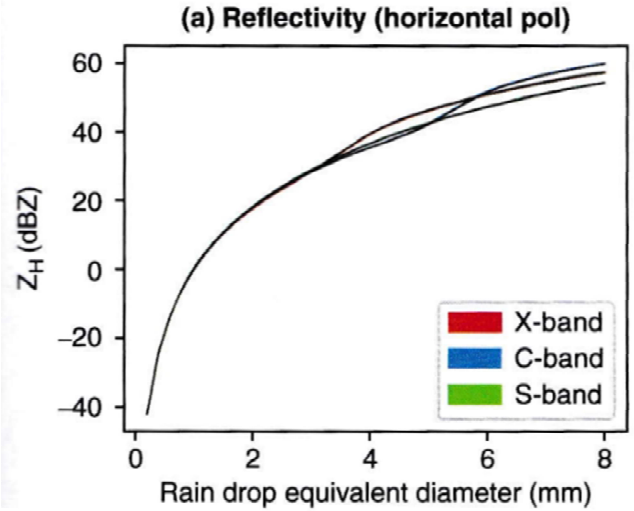


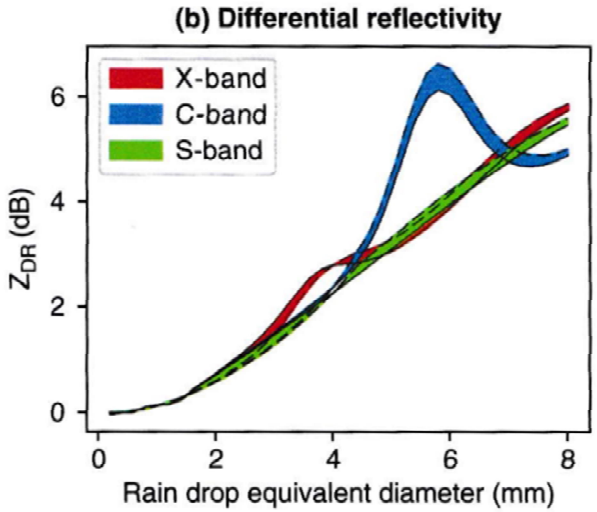
Chart of typical values of ρ_{co} for different types of targets. Image courtesy of the NOAA WDTB.

Dependency of polarimetric parameters on radar wavelength

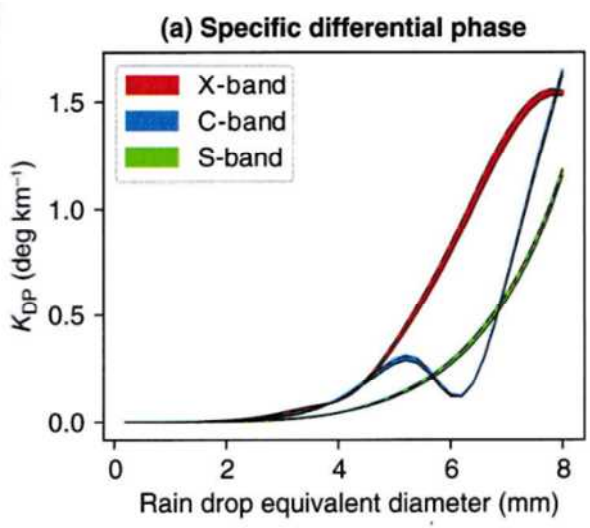
Z_h



Z_{DR}

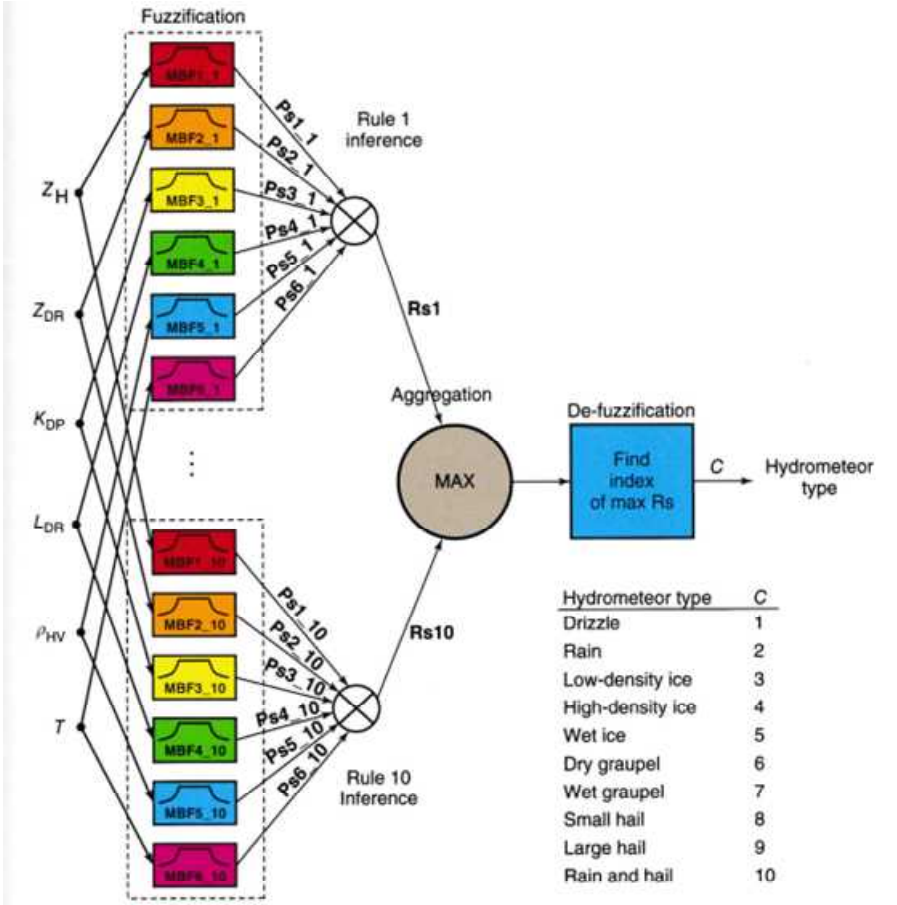


K_{DP}



Rauber and Nesbitt (2018)

Hydrometeor classification algorithm using fuzzy logic



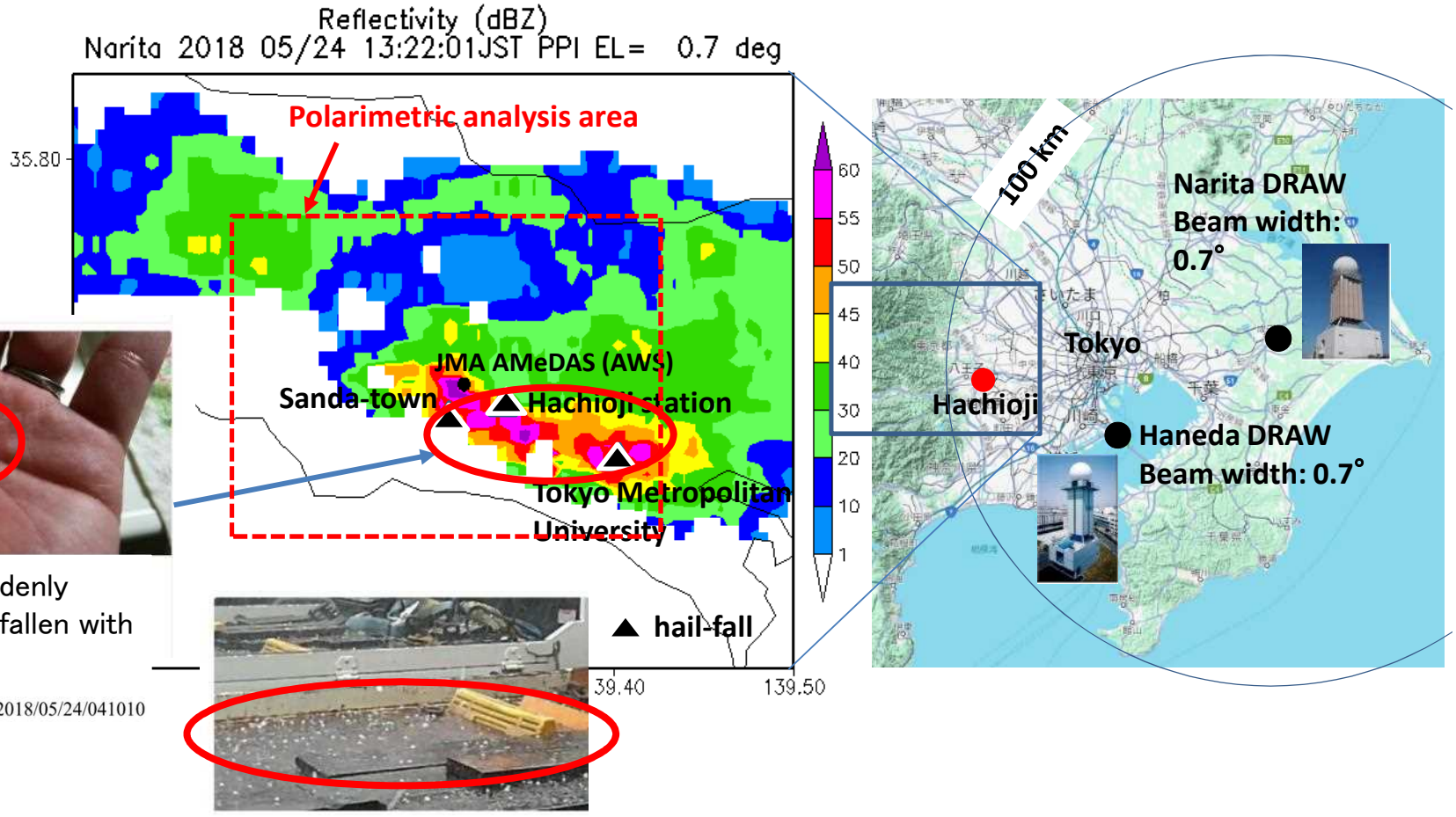
Hydrometeor type	C
Drizzle	1
Rain	2
Low-density ice	3
High-density ice	4
Wet ice	5
Dry graupel	6
Wet graupel	7
Small hail	8
Large hail	9
Rain and hail	10

Figure 7.35 Illustration of a fuzzy logic hydrometeor classification algorithm (Adapted from Liu, H. and Chandrasekar, V. (2000) Classification of hydrometeors based on polarimetric radar measurements: development of fuzzy logic and neuro-fuzzy systems, and *in situ* verification. *J. Atmos. Oceanic Technol.*, **17**, 140–164. © the American Meteorological Society, used with permission)

Rauber and Nesbitt (2018)

4. A Case Study of a Hail Thunderstorm using Polarimetric Radars

A Case Study of a Hail Thunderstorm using Polarimetric Radars
Hachioji hail event on 24 May 2018



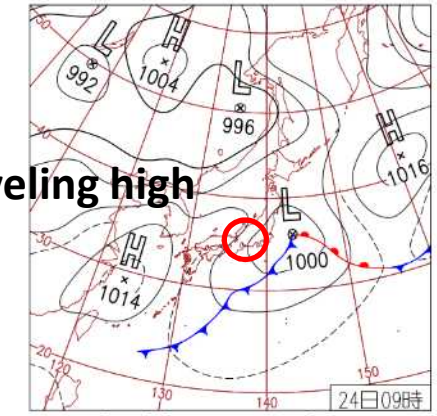
"Surprise ! Suddenly hailstones have fallen with thunder ! "

https://breaking-news.jp/2018/05/24/041010

"With a strange sound, hailstones as large as a tip of little finger have been hitting the ground !"

Synoptic situation on 24 May 2018

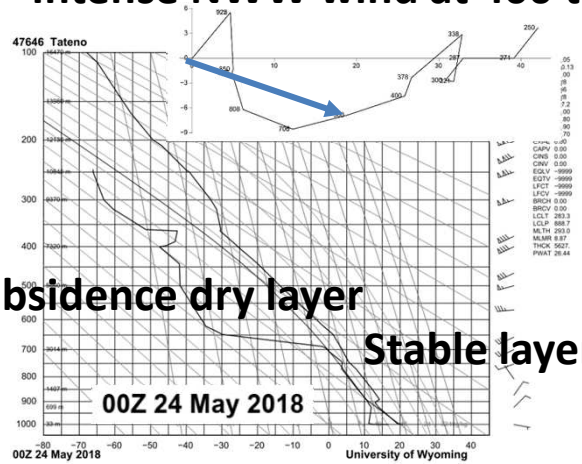
Front of a traveling high



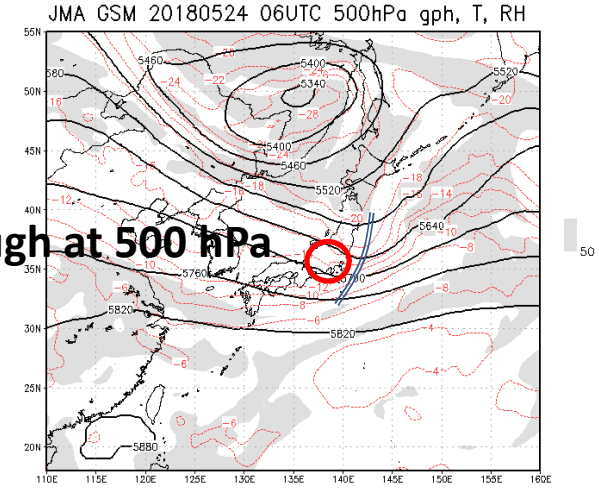
Intense NWW wind at 400 to 800 hPa

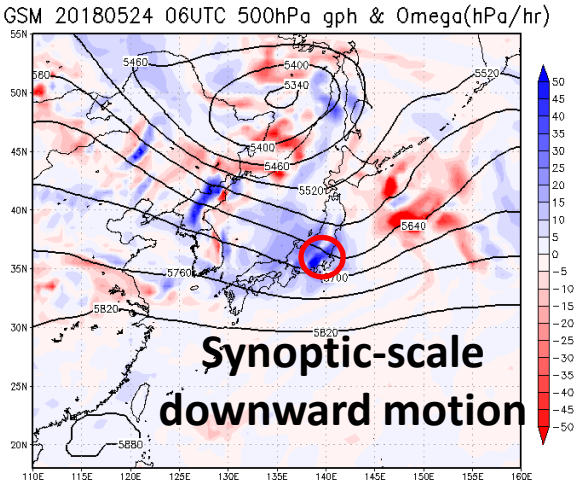
Subsidence dry layer

Stable layer at 700 hPa

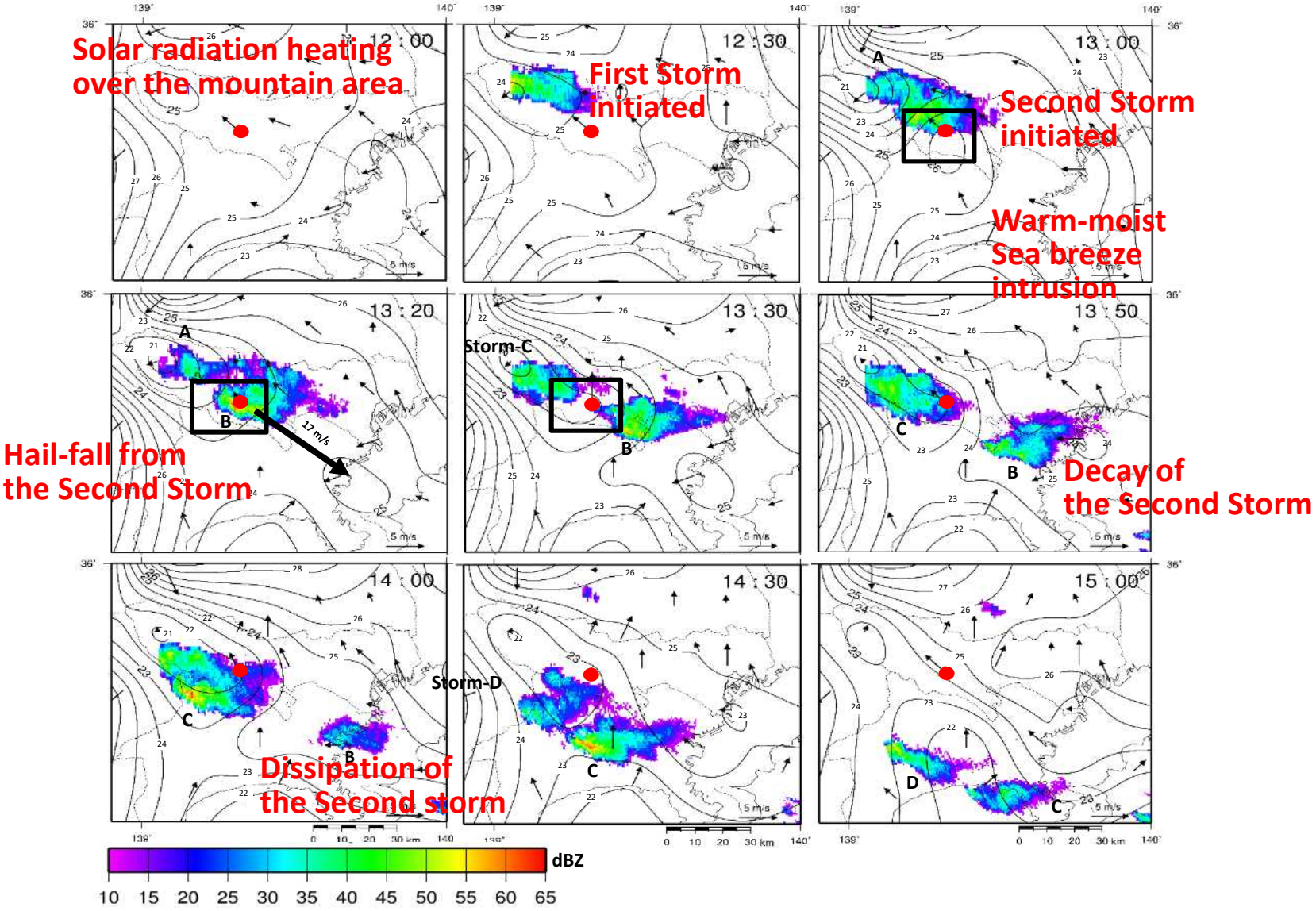


Behind a trough at 500 hPa

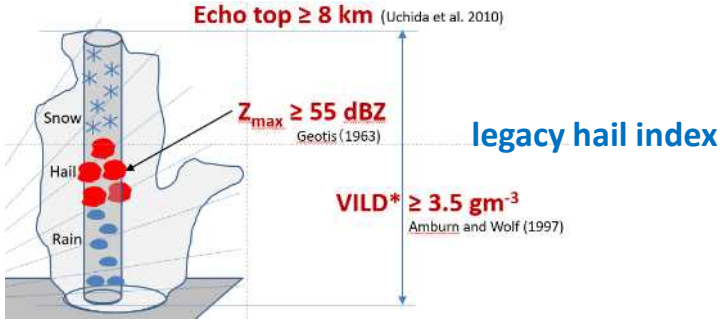




Evolution of the mother thunderstorm producing hail



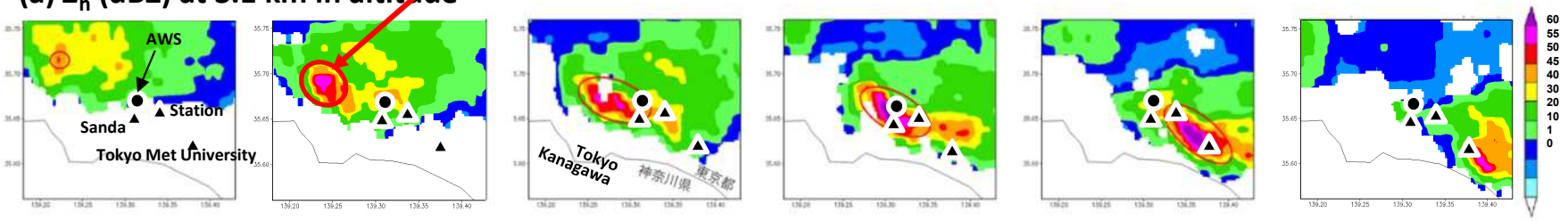
Evolution of the hail core as seen with "legacy hail index"



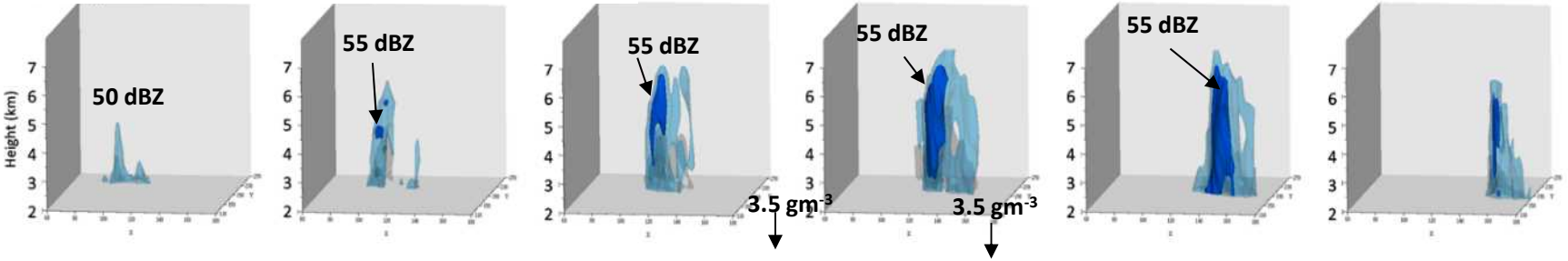
50 dBZ core

13:00 13:05 13:10 13:15 13:20 13:25

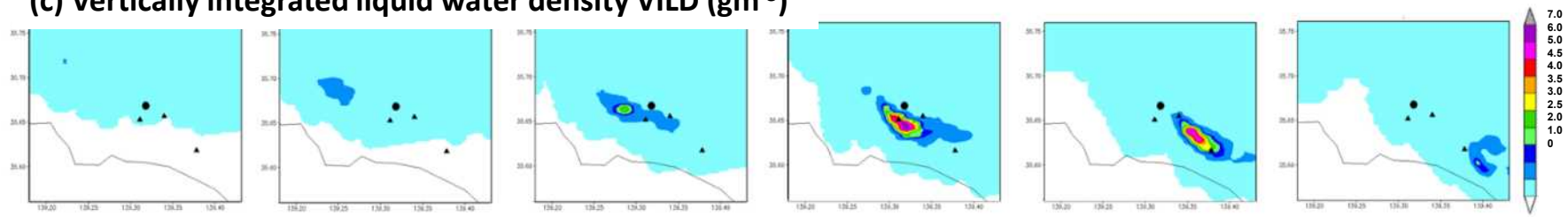
(a) Z_h (dBZ) at 3.1 km in altitude



(b) Z_h 50 dBZ and 55 dBZ Iso-surfaces

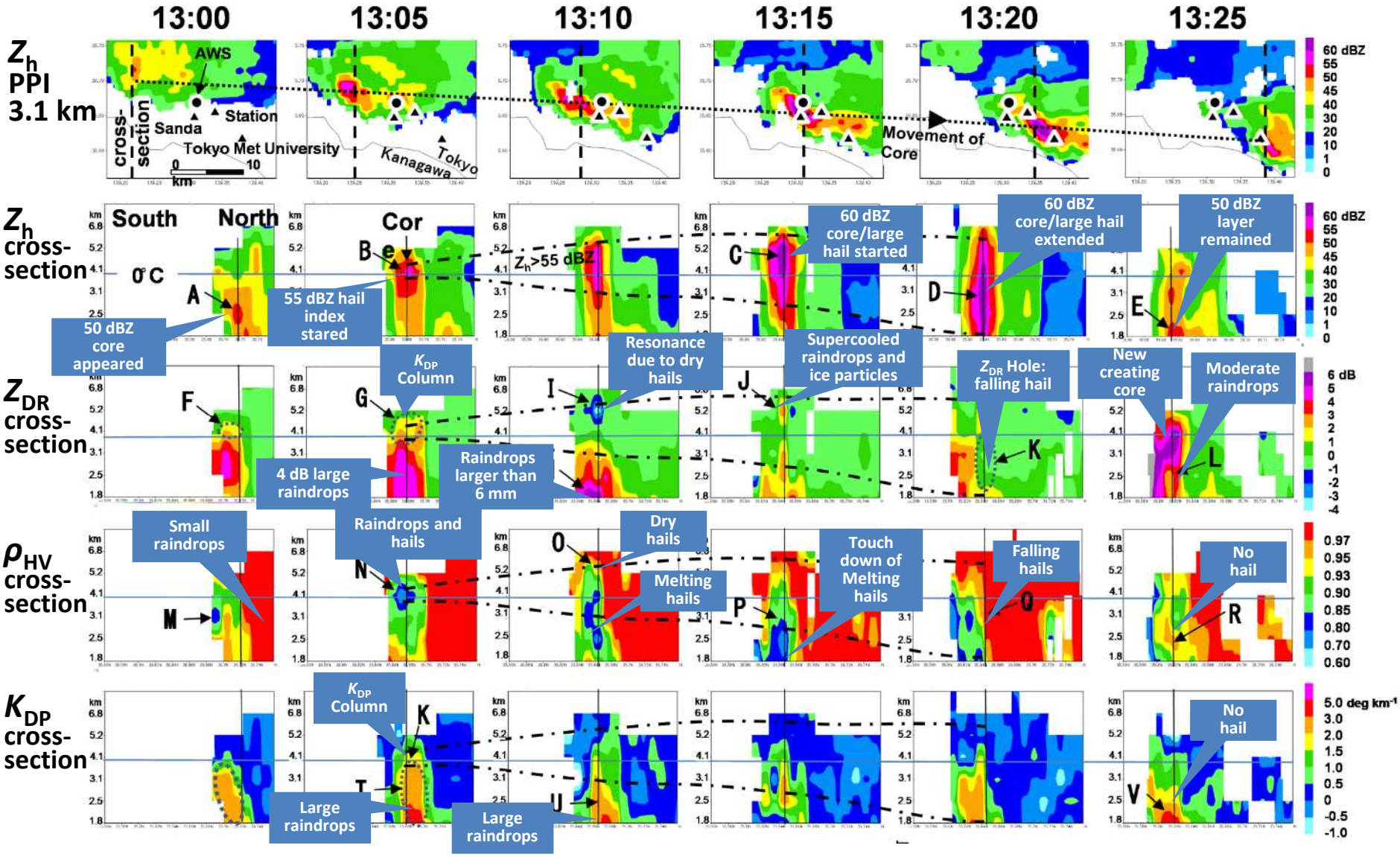


(c) Vertically integrated liquid water density VILD (gm^{-3})



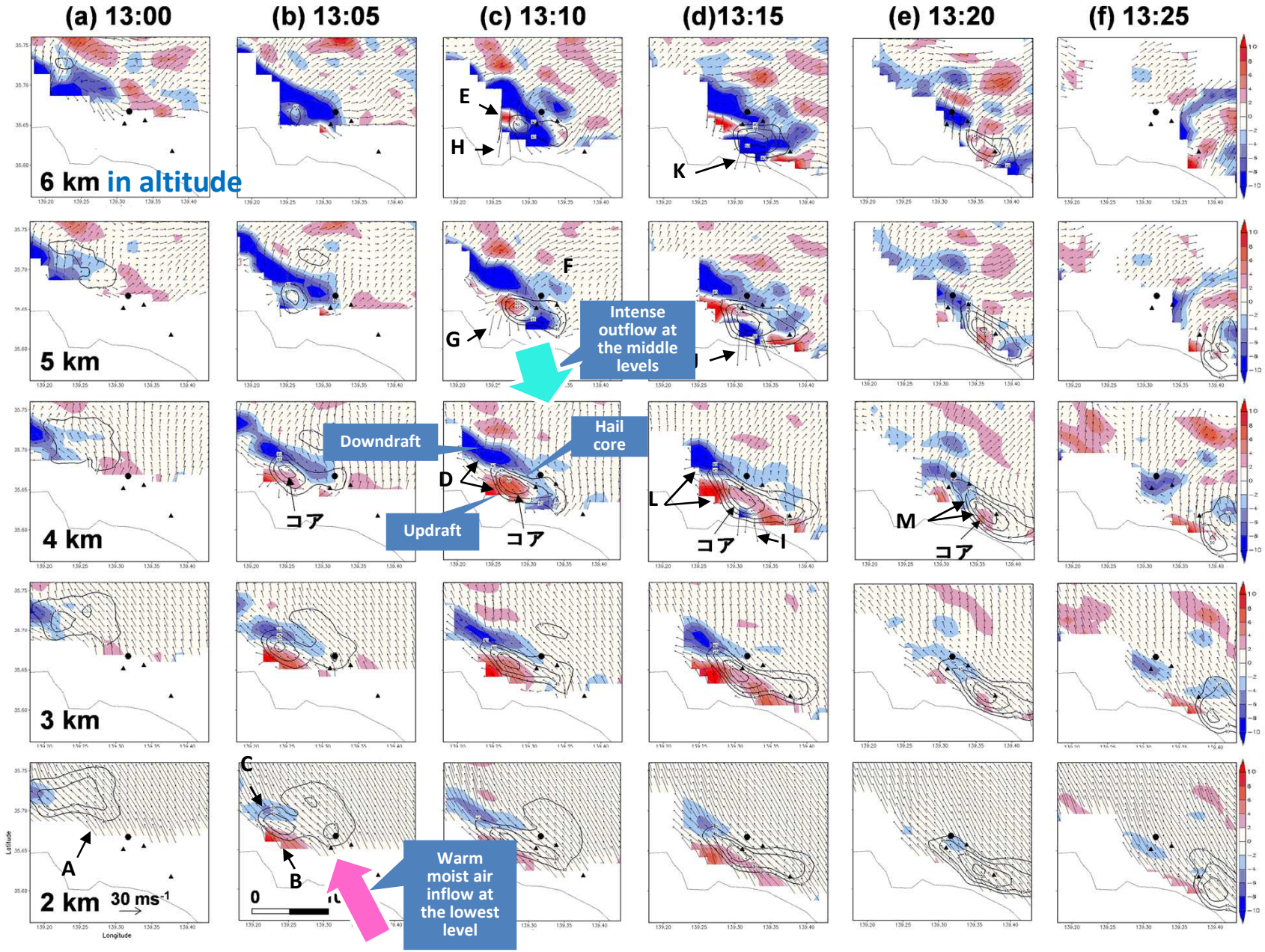
← Expected hail-fall on the ground →

Evolution of Polarimetric parameters: Z_{DR}, ρ_{HV} and K_{DP}



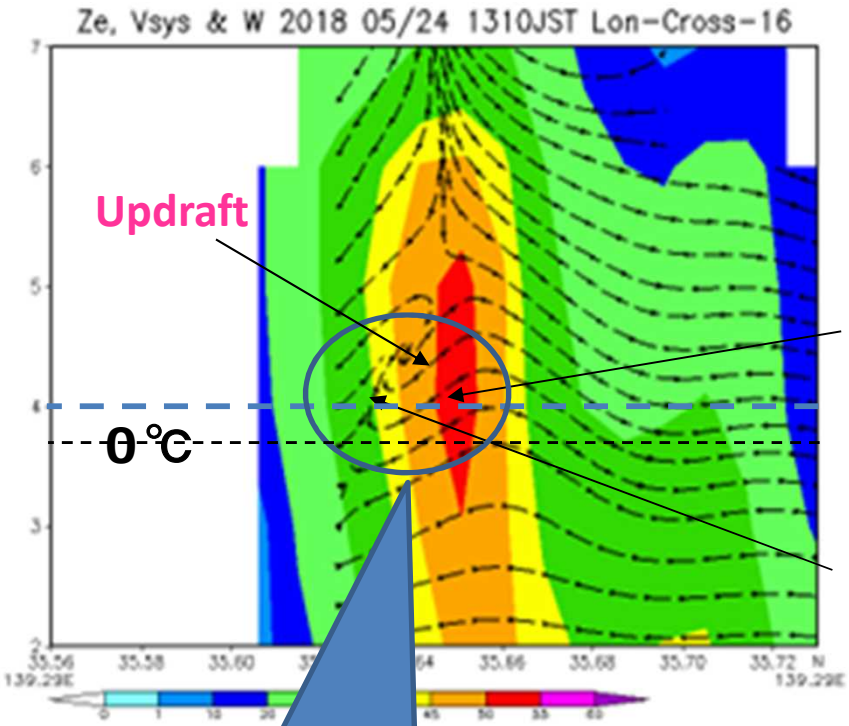
■ Evolution of kinematic structure of the hail core

System-relative horizontal wind and vertical velocity with Dual-Doppler analysis



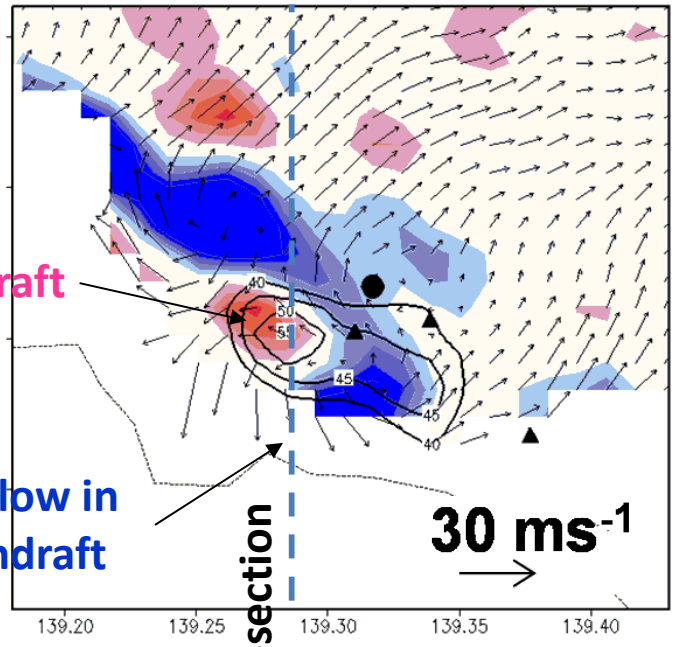
■ Hail development in an updraft-downdraft-updraft circulation

System-relative wind along the vertical cross-section at 130.29 E

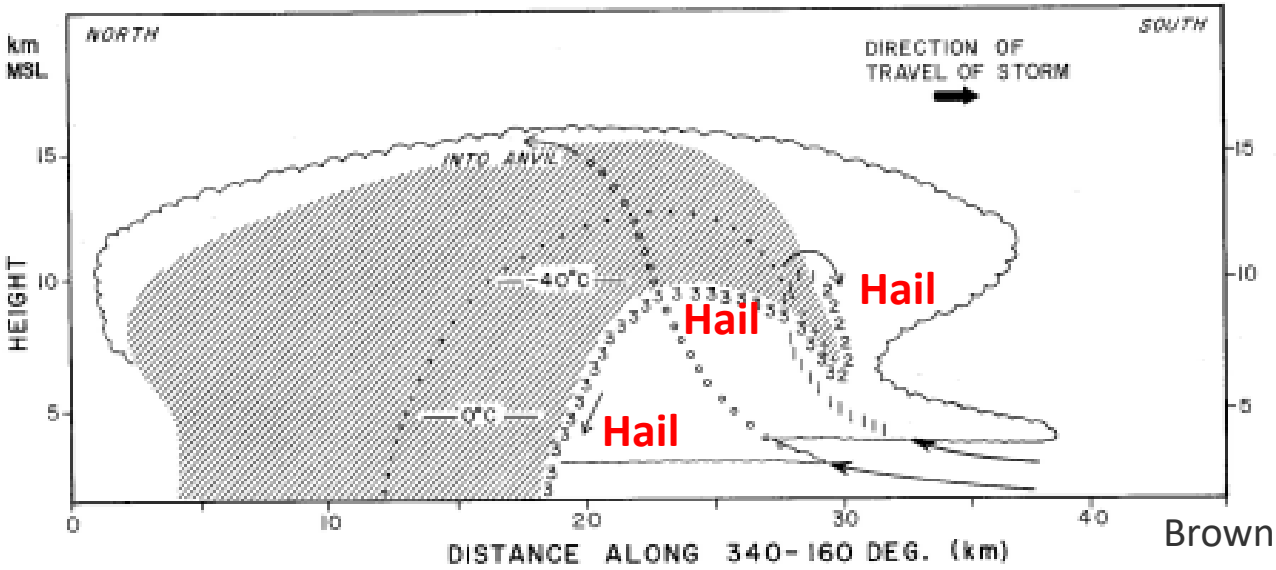


Hail development in an updraft-downdraft-updraft circulation

System-relative wind and vertical motion at 4 km in height



Classical concept model of hail-inducing storm



Browning and Foote (1976)

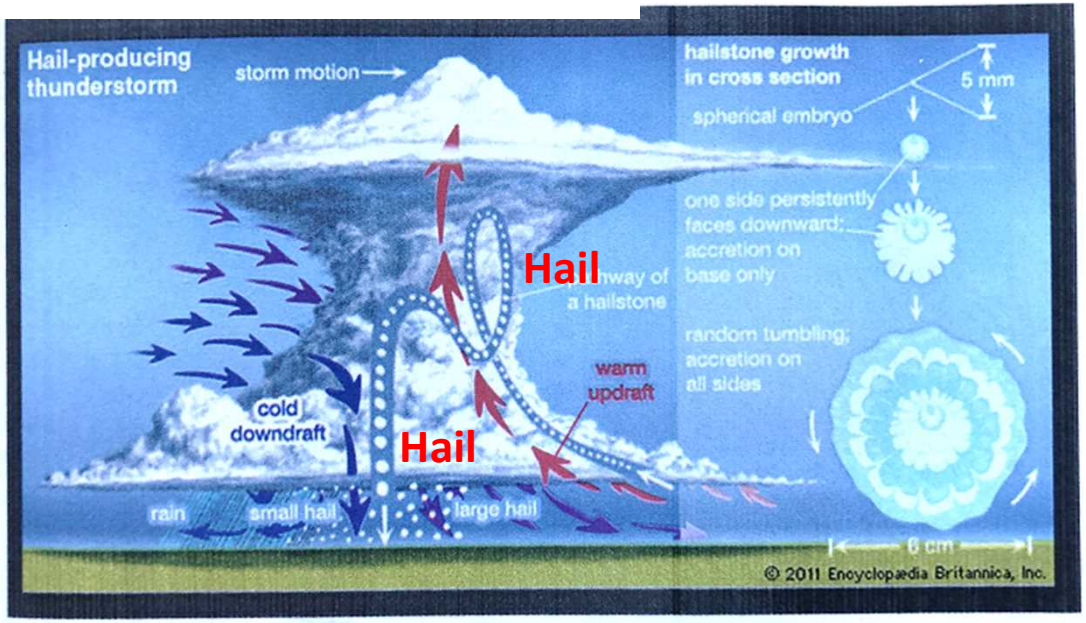
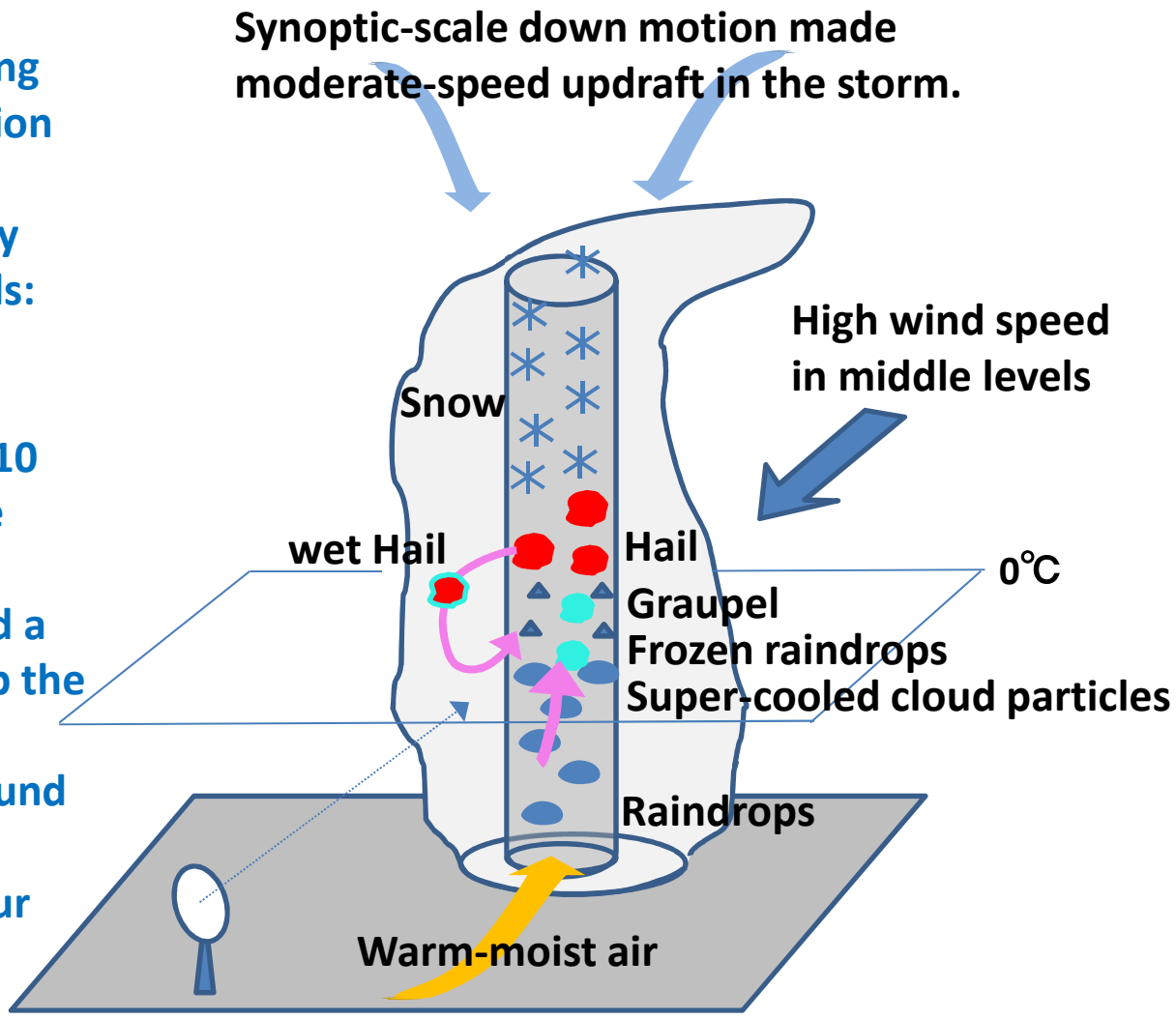


Fig. 8.4 Conceptual picture of a hailstorm. Reprinted with permission from *Encyclopedia Britannica*, © 2012 by Encyclopedia Britannica, Inc.

What I have learnt from the case study

1. The possibility of hail-fall in a moderately developed thunderstorm is estimated using traditional (legacy) hail detection methods.
2. Polarimetric parameters clearly traced the whole stages of hails: production, growth and decay stages.
3. Hails aloft could be identified 10 minutes before they got to the ground.
4. Dual-Doppler analysis revealed a unique air-flow pattern to help the growth of hails in the storm: an up-down-up circulation around the 0 ℃ layer.
5. What should we do next in your weather services:
   Hail advisory?
   Hail nowcasting??
   Hail damage mitigation???



Conceptual model of the hail-induced thunderstorm on 24 May 2018

Thank you

March 2014

February 2018

Appendix

JICA's cooperation for Meteorological Service
- JICA Grant Aid –

JICA has installations weather radar weather radar as early warning systems particularly for typhoon / tropical cyclone disaster since 1986

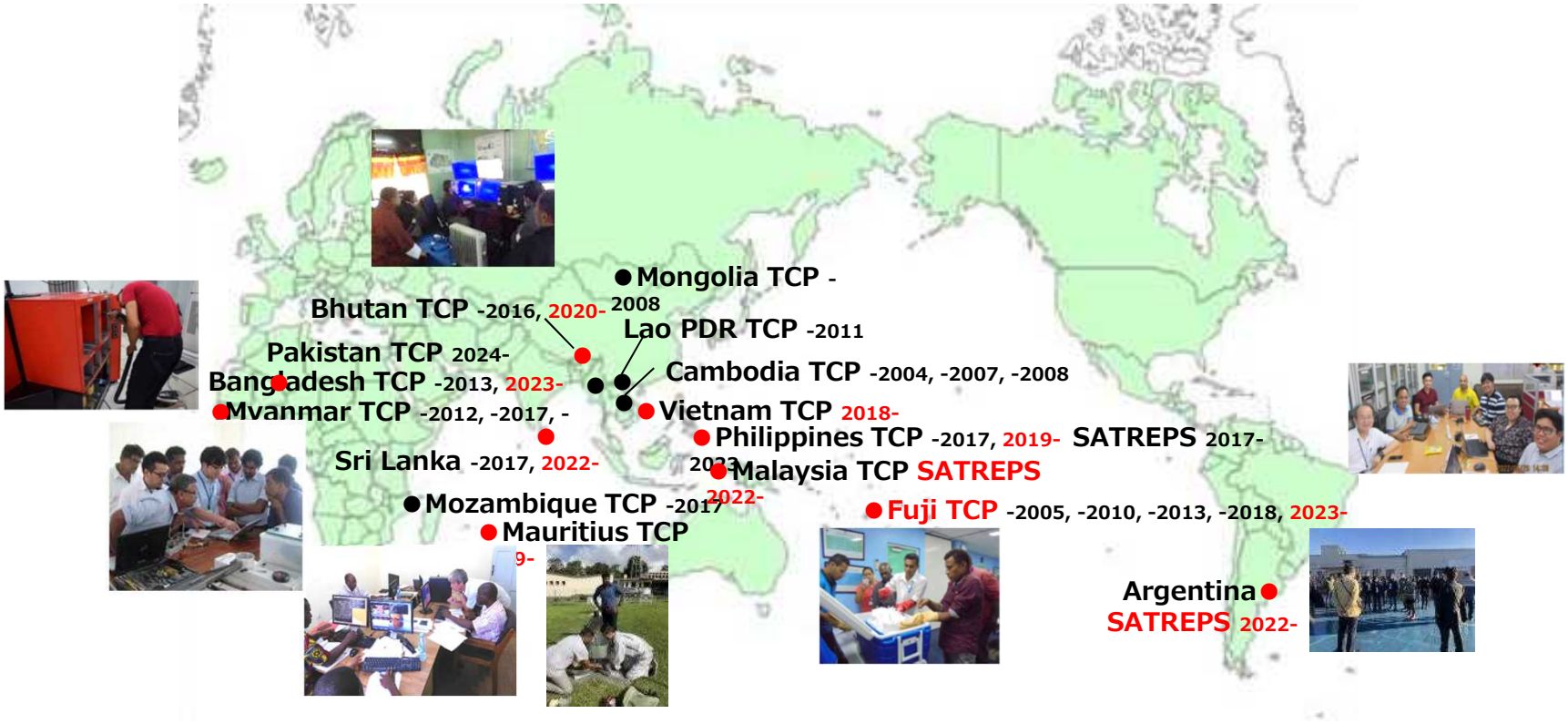
as for 2023

Appendix

JICA's cooperation for Meteorological Service

- Technical Cooperation Projects (TCP) –

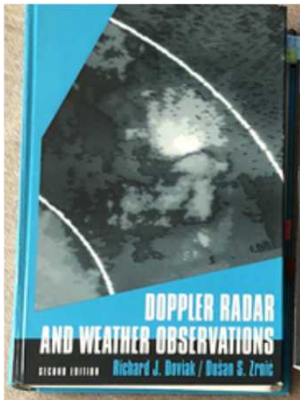
- Science and Technology Research Partnership for Sustainable Development (SATREPS) -



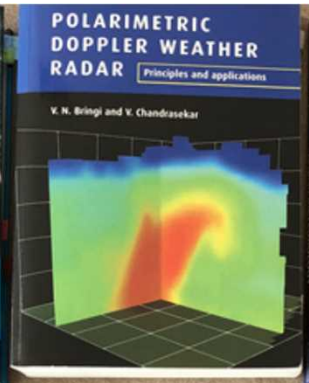
Appendix

■Textbooks on Polarimetric Radar

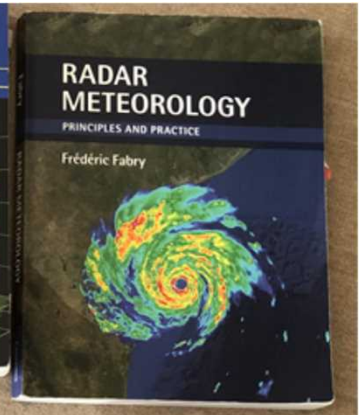
1984、1993



2001



2015



2023

解　説

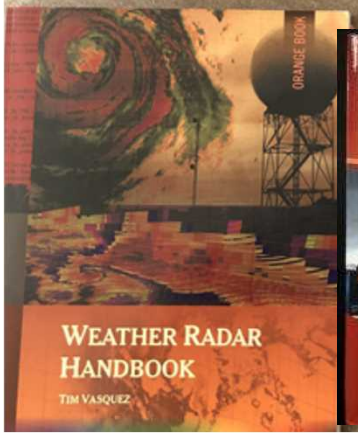
固体素子二重偏波気象レーダーの導入と今後の展望

大気海洋部観測整備計画課[1]

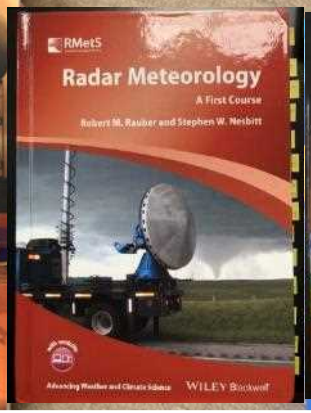
要　旨

気象庁では，全国 20 か所の一般気象レーダー及び全国 9 空港の空港気象ドップラーレーダーについて，電波増幅部に半導体を利用した C バンド固体素子二重偏波気象レーダーへの設備更新を進めている．固体素子送信機と二重偏波気象レーダーが有する数多くの利点は，それぞれが相まってこれまでの気象レーダー観測における課題の多くを打破するに留まらず，更なるブレークスルーをもたらす可能性も秘めている．本稿では，導入した気象レーダーの概要とともに，更新による改善点（降水強度の推定精度向上，品質管理機能の強化，観測の高頻度化・高解像度化など）や偏波パラメータの校正・モニタリングに係る取組について解説する．また，今後の展望として，降水強度推定の更なる精度向上や各種ナウキャストの精度向上，数値予報への利用など二重偏波気象レーダーの導入により実現が期待される技術についても紹介する．

2015



2018



2019