Utilization of Dual-pol data

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Dual-pol parameters

- Z_{DR} : Differential reflectivity : Shape of particle
  - Ratio between horizontal and vertical reflectivity.
  - Information on aspect ratio of scattering targets.
- ρ_{hv} : Correlation coefficient : Diversity of shape
  - Correlation coefficient between horizontal and vertical signal.
  - Information on aspect ratio variation of scattering targets.
- Φ_{DP}: Differential phase : Rain rate / Water content

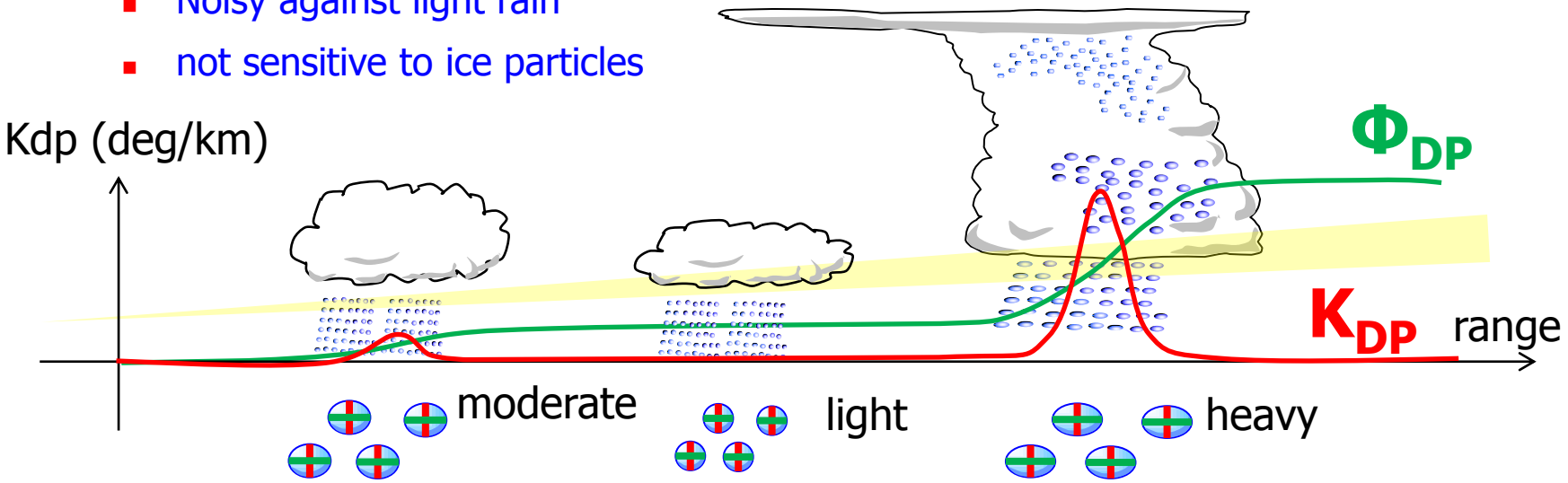
  K_{DP} : Specific differential phase
  - Phase difference between horizontal and vertical signal.
  - Information on aspect ratios of propagation medium.
- Textures of polarimetric parameters are also useful

Rain rate estimation

- Estimation using a Z-R relation alone suffers from
  - attenuation by rain
  - sensitiveness to drop size distribution (DSD)
- Using a Kdp-R relation improve estimation accuracy for heavy rain.
  - Kdp is not affected by rain attenuation
  - Kdp-R relation is less sensitive to DSD
- Z-R relation is still needed for light rain (and solid precipitation).
  - Kdp is noisy for light rain

Kdp: Specific differential phase

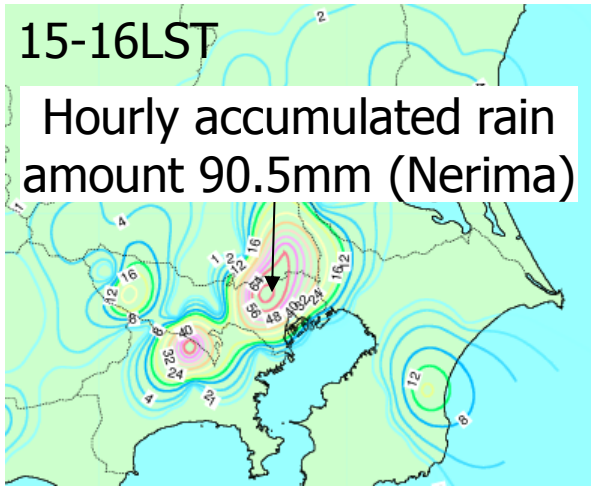
- K_{DP}: Rain rate / Water content
  - Change of Φ_{DP} in a unit distance
  - Reflects aspect ratios of precipitation particles on the beam path.
  - Possible range of values : generally -2 to 10 (deg/km)
  - Not affected by rain attenuation
  - Useful for rainfall rate estimation (especially for heavy rain)
  - Noisy against light rain
  - not sensitive to ice particles



Courtesy of Mr. Umehara

Record Heavy Rainfall of 26 August 2011

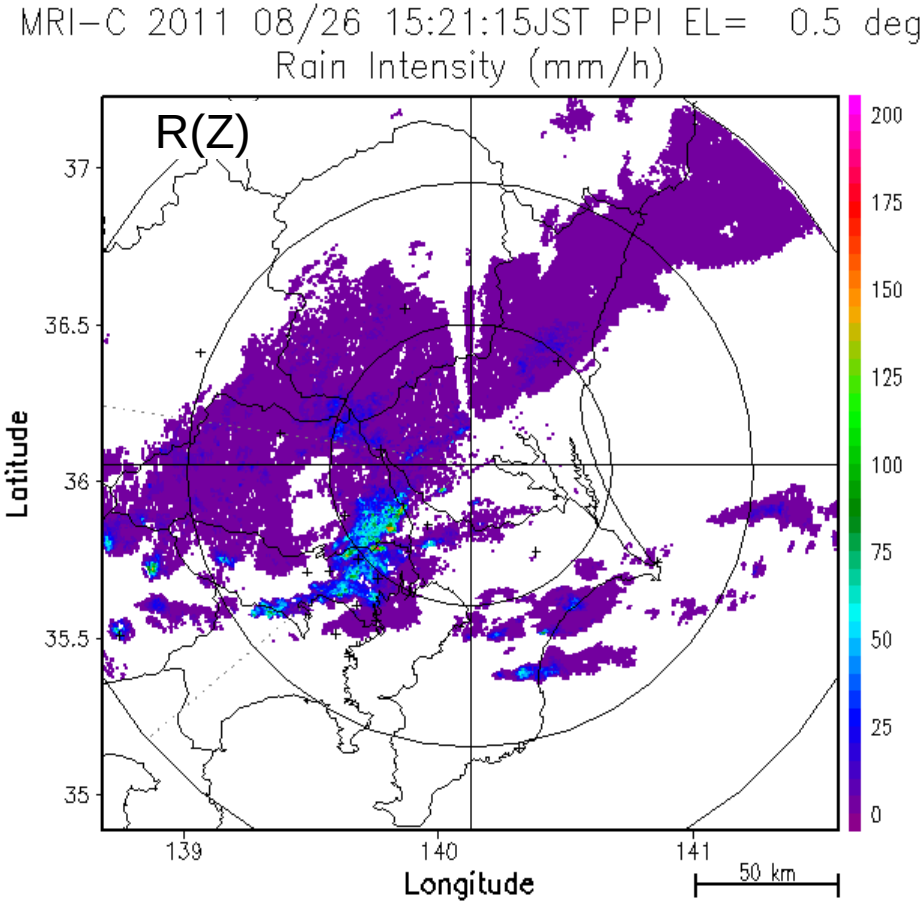
- Occurred in Tokyo metropolitan area.
- Maximum hourly accumulated rain amount was 90.5mm.
- Number of reported flooding damages were 175.

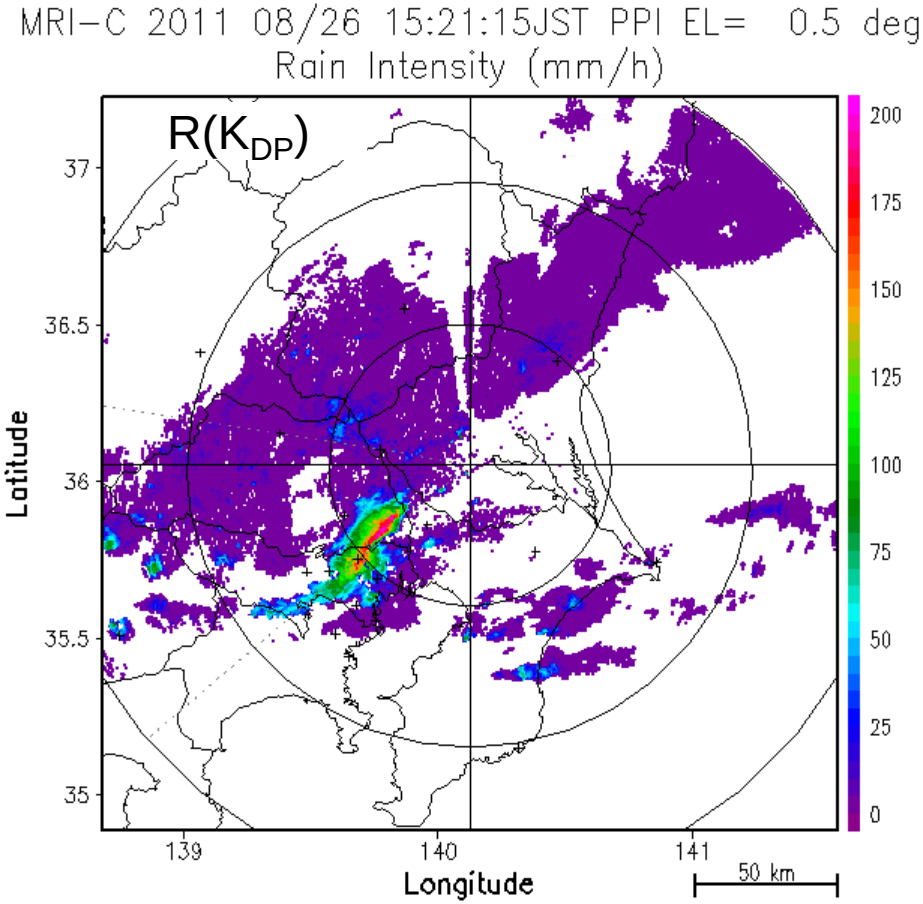


Rain rate estimation with K_{DP}

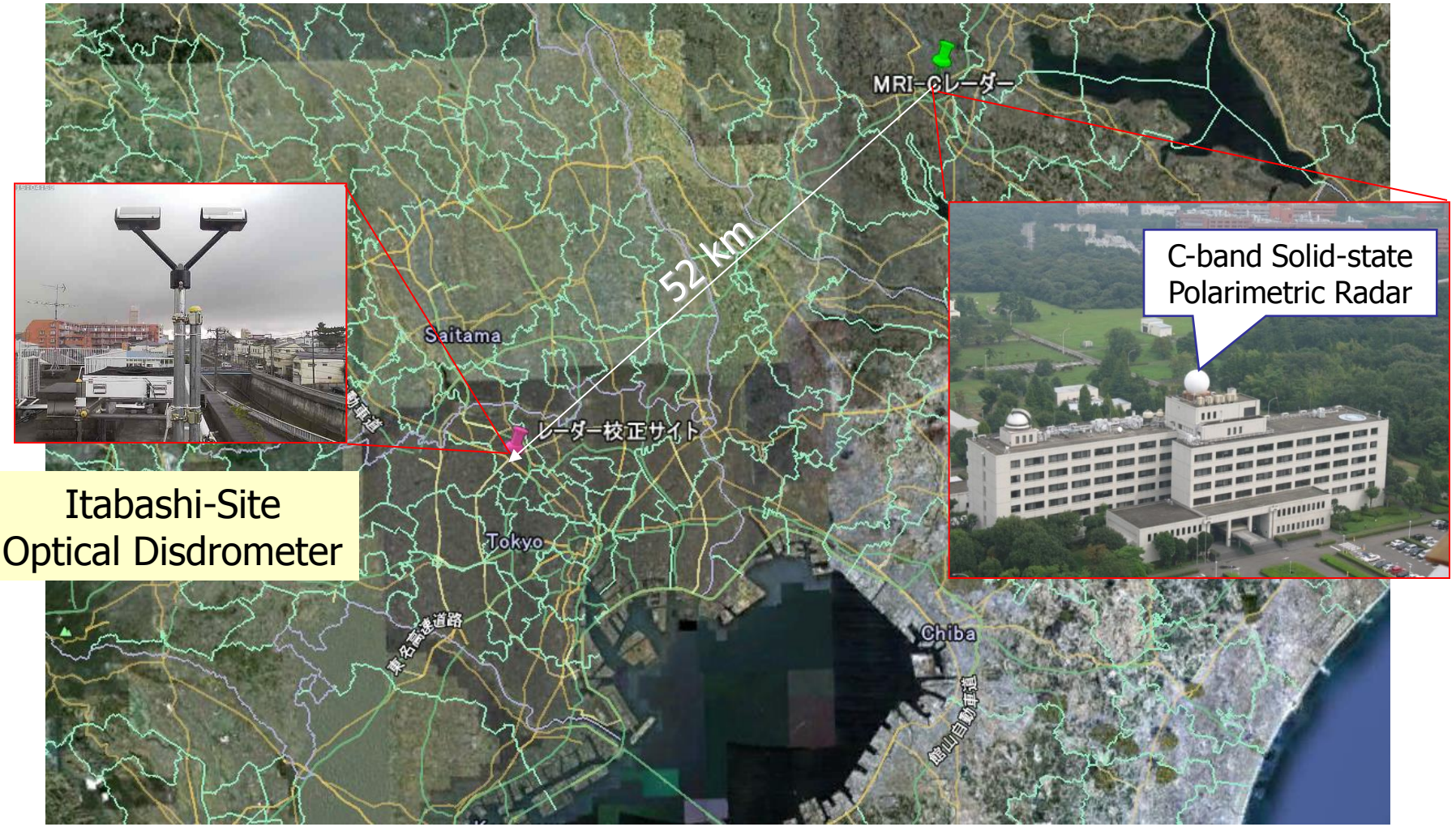
- $R(K_{DP}) = 129(K_{DP} / f)^{0.85}$ (if $K_{DP} >= 1^{o}km^{-1}$ and $Z >= 30dBZ$)
- $R(Z) = 0.0365 \cdot 10^{0.0625Z}$

f : transmitting frequency in GHz



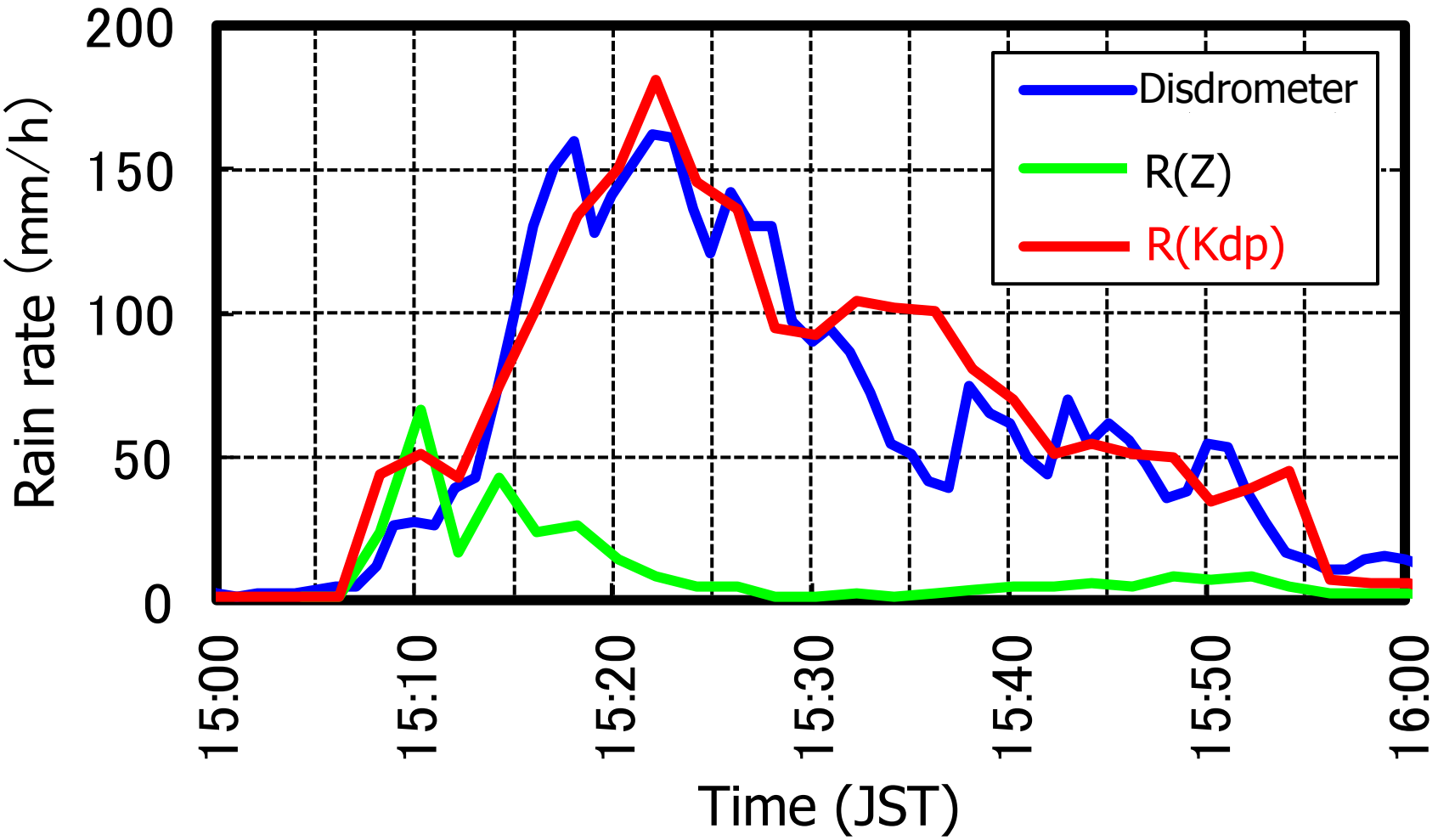


Locations of Observation Equipments



Rain rate estimation with K_{DP}

- $R(K_{DP})$ is consistent with Disdrometer observation.



Hydrometer Classification

Hydrometers can be classified according to their dual-pol characteristics.

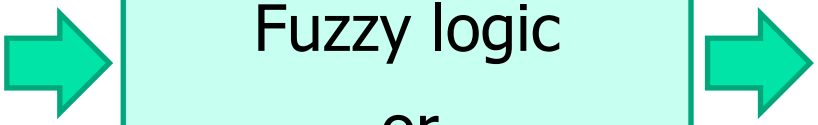
	Z [dBZ]	ρhv	Kdp [deg/km]	Zdr [dB]
Drizzle	< 25	> 0.99	0	0
Rain	25 - 60	> 0.97	0 - 10	0.5 - 4
Ice crystal	< 25	> 0.95	0 - 1	0 - 5
Dry snow	< 35	> 0.99	0 - 0.5	0 - 5.0
Wet snow	< 45	0.8 - 0.95	0 - 2	0 - 3
Dry graupel	40 - 50	> 0.99	-0.5 - 0.5	-0.5 - 1
Wet graupel	40 - 5	> 0.99	-0.5 - 2	-0.5 - 3
Hail < 2cm	50 - 60	> 0.95	-0.5 - 0.5	-0.5 - 0.5
Hail > 2cm	55 - 70	> 0.96	-1 - 1	< -0.5

For S-band

Doviak and Zrnic, 1993

Hydrometer Classification

Input parameters
Z
V
W
Zdr
ρhv
Kdp
S(Z)
S(Zdr)
S(ρhv)
S(Φdp)
Etc…



Classification Algorithm

Bayesian

or

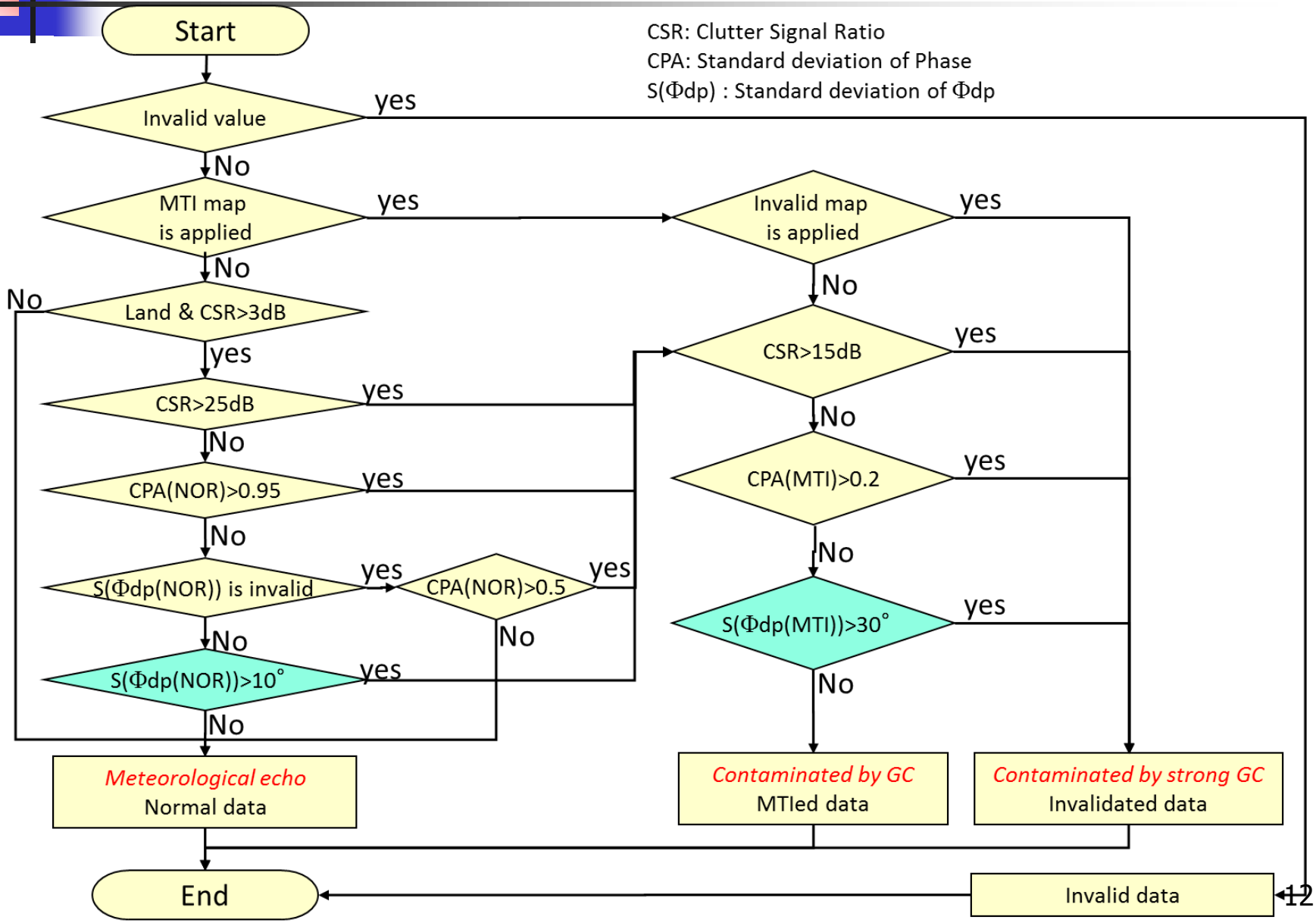
Fuzzy logic

or

Decision Tree

Output parameters
Drizzle
Rain
Ice crystal
Dry snow
Wet snow
Dry graupel
Wet graupel
Hail < 2cm
Hail > 2cm

Example of decision tree



Example of hydrometer classification

Dual-pol data

Z_{hh_corr}

Z_{dr_corr}

ρ_{hv}

K_{dp}

V_{sw}

$\sigma(Z_{dr})$

$\sigma(\psi_{dp})$

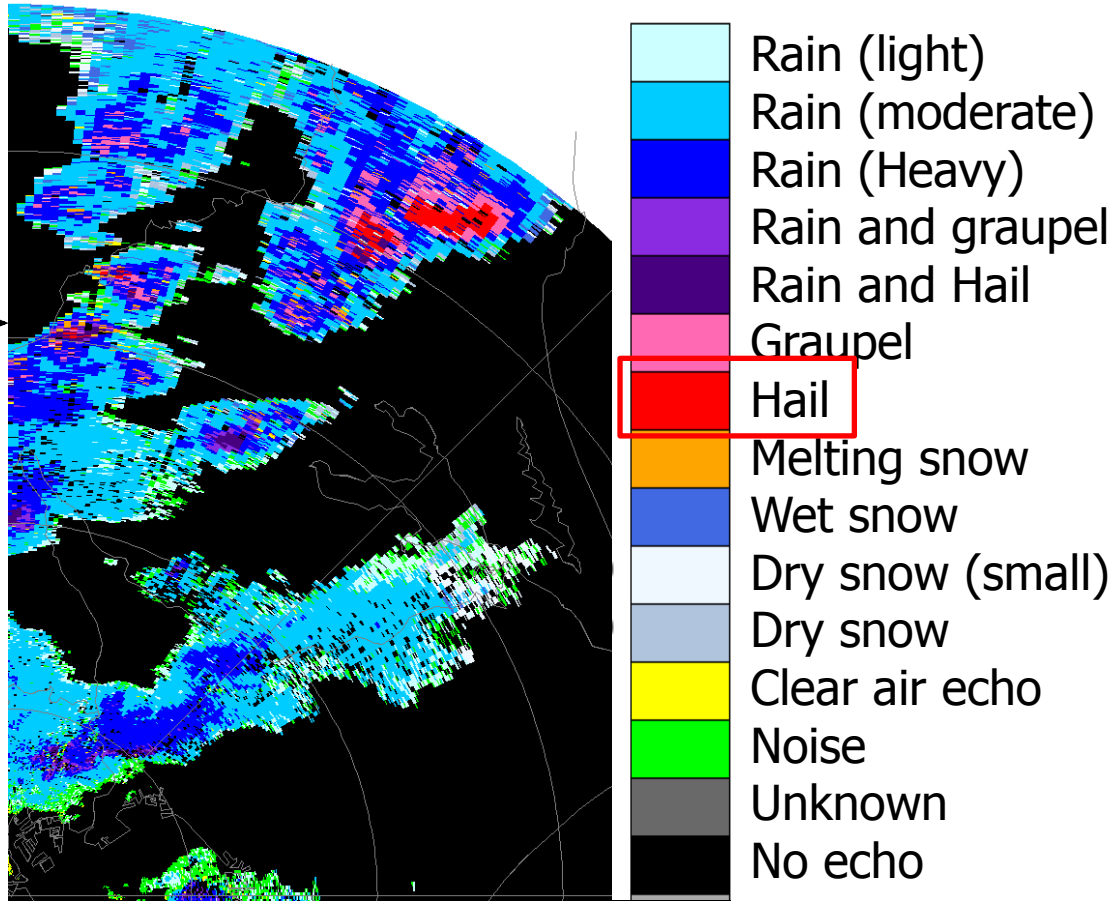
$\sigma(\rho_{hv})$

Δz_0

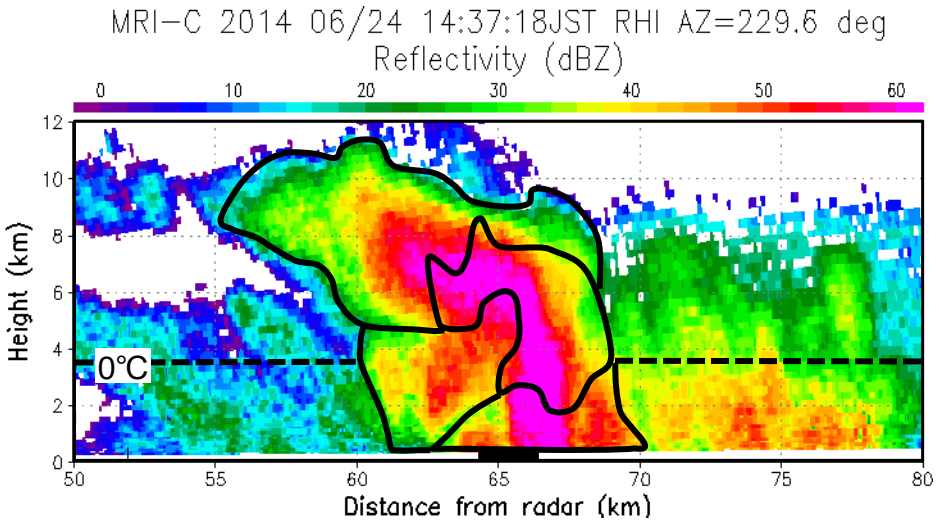
Classify hydrometer types using Bayesian classification

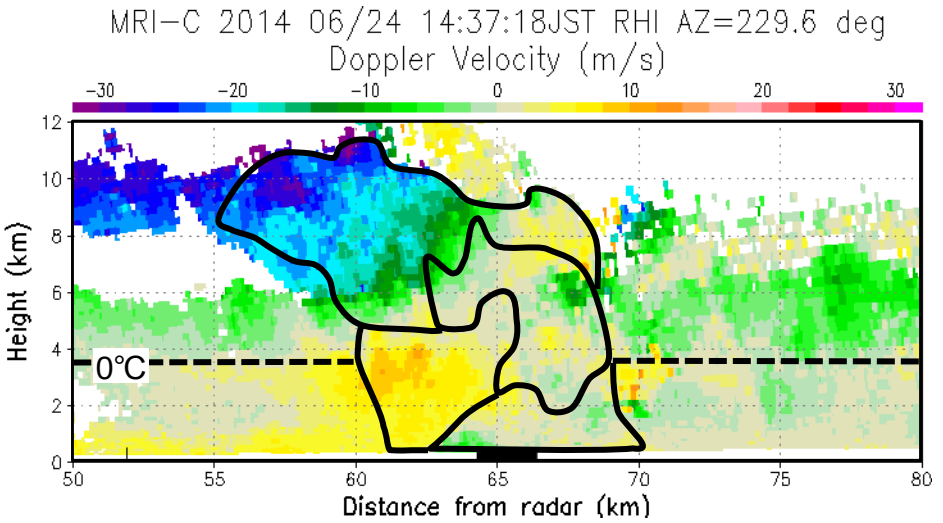
Freezing level information from Numerical weather prediction model

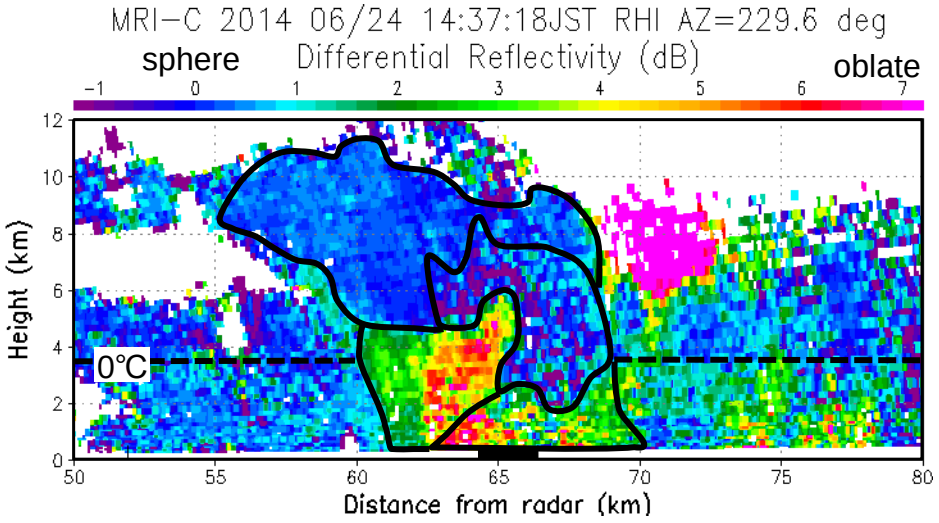
Case of hail storm on 14 July 2016

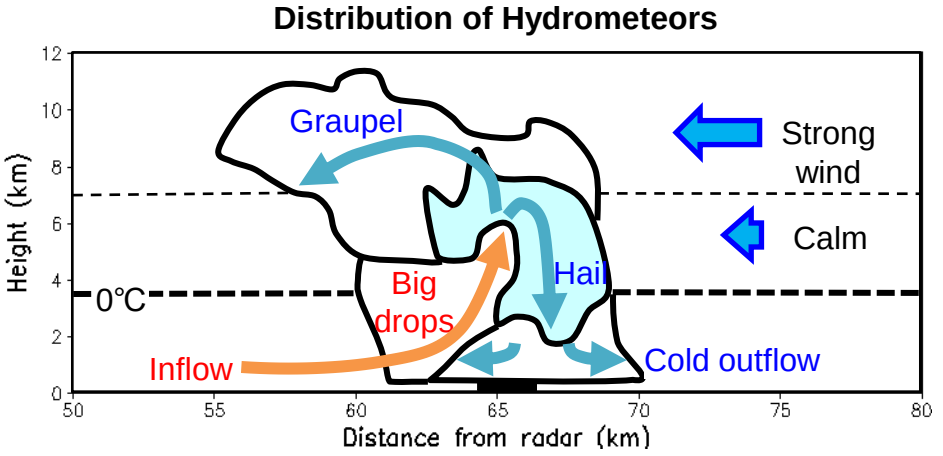


Identification of hail



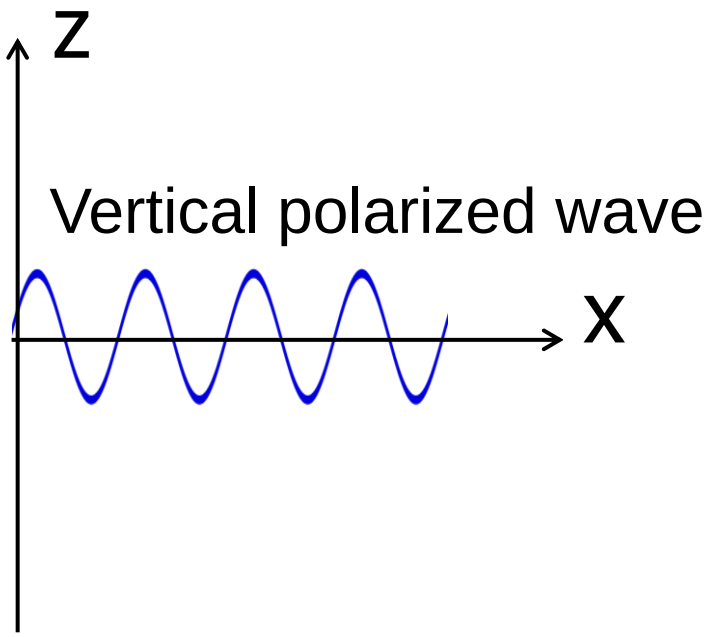




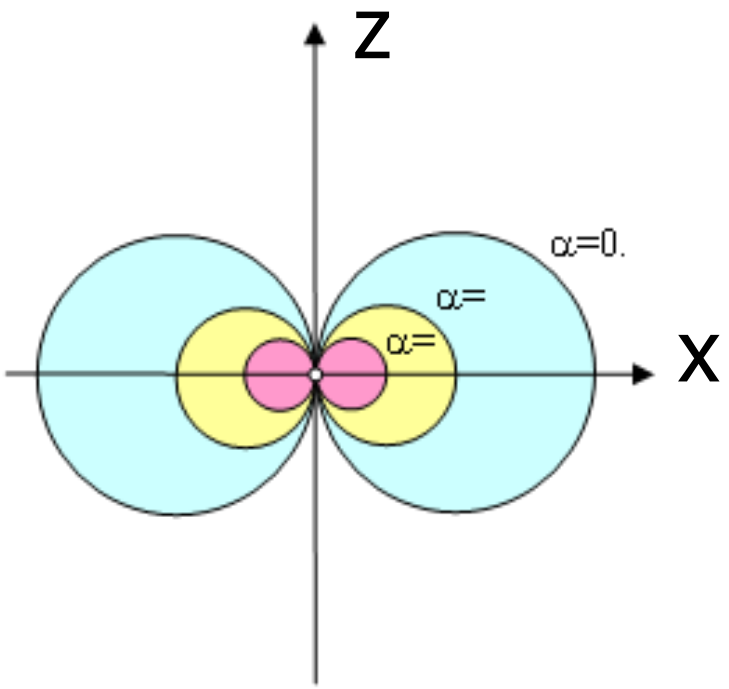


Why is Zdr of TBSS just behind hail large

Vertical polarized wave is hardly scattered to the vertical direction.



Radiation pattern from dipole



Tsukuba Tornado of 6 May 2012

- F3, damage path length was 17km.
- Supercell tornado.
- Killed 1 person. Number of damaged buildings were about 1000.

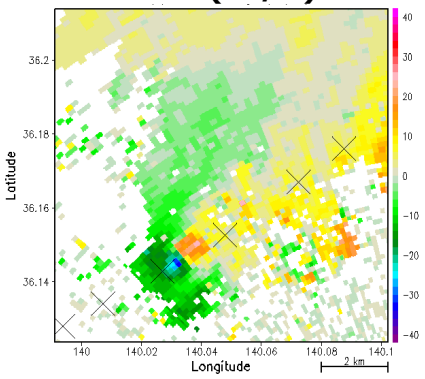
Photo taken by Mr. Itonaga

Hydrometer / scattering target discrimination

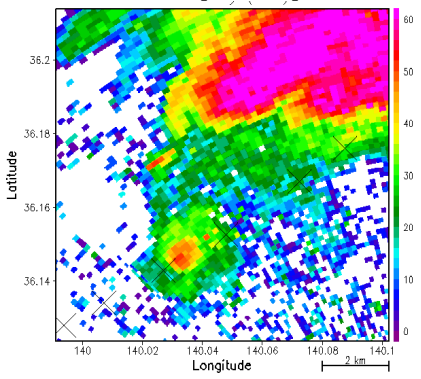
*1 : Doviak and Zrnic 1993
*2 : Anderson et al 2011
*3 : Ryzkov et al 2005

Target	Z (dBZ)	ρhv	Zdr (dB)
Rain	small - large 25 - 60*1	large 0.97< *1	small - large 0.4 - 4*1
Hail	large 50< *2	middle 0.95< *1	middle - large 3 - 8*2
Clear echo (Insects, Chaffs)	small < 25	small < 0.8	large 5<
Tornadic debris	small - large 20<	small*3 < 0.8	small*3 - 0 -

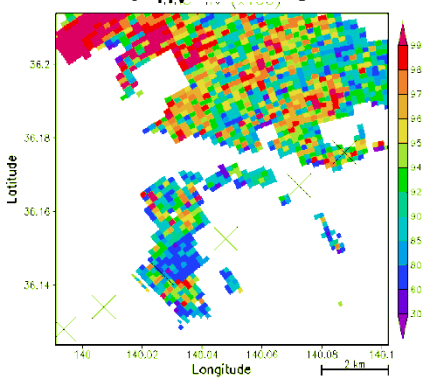
V(m/s)



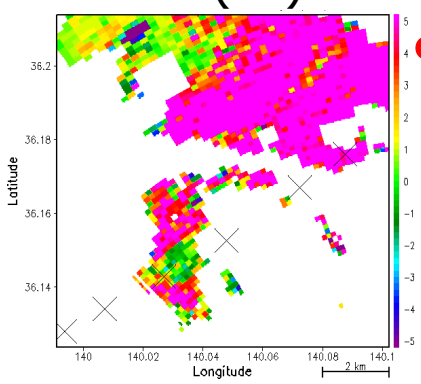
Z(dBZ)



ρ_{hv}(x100)



Zdr (dB)



oblate

sphere

Summary

- Rain rate estimation
  - Kdp is useful for heavy rainfall
  - Z is needed for light and solid precipitation
  - Zdr is also useful but is needed for high accuracy
- Hydrometer classification
  - Many outputs from many inputs
  - Accurate dual-pol data are needed
  - Training data / evaluation data is crucial