ATMO 689 Lecture #11 (11-23-04)
Polarimetric Radar Properties of Ice Crystals and Aggregates (Stratiform Precipitation) (BC Ch. 7.3)

• Aircraft and dual-polarization radar (Zh and Zdr) signatures of ice in stratiform precipitation
  – Bader et al. (1987, QJRMS)
  – Vivekanandan et al. (1994, IEEE TGRS)
• The “ice-crystal” line in Zh-Zdp space:
  – Aydin and Walsh (1998)
• Using Kdp to estimate Ice Water Content (IWC) in stratiform ice precipitation.
  – “Cold” vs “warm” snow: Zdr vs. Kdp
  – Ryzhkov et al. (1998)
• Polarimetric signatures in the stratiform bright-band (i.e., melting layer)
  – Beaver and Bringi (1997, Proc IEEE)
Stratiform Ice Precipitation: Comparison of Zh/Zdr to aircraft probe data

Low Zh (5-15 dBZ) and high Zdr (2-4 dB) associated with planar crystals (e.g., stellar).

Bader et al. (1987, QJRMS)
Stratiform Ice Precipitation: Comparison of Zh/Zdr to aircraft probe data

No variation in density or riming noted. Higher Zh (15-25 dBZ) and lower Zdr (0.5-1.5 dB) associated with presence of aggregates.

Bader et al. (1987, QJRMS)
Stratiform Ice Precipitation: Comparison of Zh/Zdr to aircraft probe data

Region I: Low Zh and High Zdr

Region II: Higher Zh and Lower Zdr

Vivekanandan et al. (1994)
Stratiform Ice Precipitation: Comparison of Zh/Zdr to aircraft probe data

**Region I**

- Ice hydrometeor distribution dominated by small (2.4 mm) dendrites, resulting in low Zh and high Zdr. Spread of values likely associated with differing fractions of aggregates.

**Region II**

- Mixture of ice larger aggregates and rimed dendrites, resulting in larger Zh and near zero Zdr.

**Key Lesson:** Small amount of aggregates will tend to dominate Zdr!

Vivekanandan et al. (1994); see also BC2001 Fig. 7.68
The “ice crystal” line in Zh-Zdp space

- Equivalent to the rain-line technique shown earlier.
- Similar types of ice crystals (e.g., stellar vs. columnar) give different ice-crystal lines.
- Aydin and Walsh (1998) used modeled columnar and planar ice crystals to estimate theoretical ice-crystal lines.
  - Also showed real data in stellar ice crystals at 95 GHz (W-band).
- Once ice crystal type is known, deviation to the left of the given ice crystal line would denote presence of aggregation.
  - Could estimate fraction of aggregated ice in a similar fashion as ice fraction was computed before with rain-ice mixture.

BC2001 Fig. 7.69 (from Aydin and Walsh 1998)
Using Kdp to estimate IWC in stratiform ice precipitation

Vivekanandan et al. (1994) showed that Kdp could be used to estimate IWC, assuming some knowledge of the axis ratio ($r$) and ice density ($\rho$).

$$K_{dp} = \frac{47.4}{\lambda} (1 - r)^{1.2} \rho^{-0.033} IWC, \quad (31)$$

Ryzhkov et al. (1998) extended the results of Vivekanandan et al (1994) and suggested that IWC could be estimated directly from Kdp and Zdr, since Zdr provides information on “r”.

We can write (27) in a slightly different form:

$$IWC = CK_{DP}/(1 - Z_{DR}^{-1}), \quad (29)$$

where $C = C_1 \lambda/30 \pi$; that is, the ice water content estimate can be obtained solely from the measurements of $K_{DP}$ and $Z_{DR}$ [expressed in linear scale in (29)].

Figure and equations from Ryzhkov et al. (1998, JAM)
Cold vs. Warm Snow: Zdr vs. Kdp

- **Cold snow** tended to be dominated by pristine ice and moderately aggregated ice crystals.
- **Warm snow** tended to be associated with heavily aggregated snow and much higher reflectivity.
- Presence of large snow aggregates drives Zdr toward zero while Kdp is only sensitive to the oriented pristine ice crystals.
- As a result, the cold snow have slightly larger Zdr than the warm snow for a given Kdp.

BC2001 Figure 7.67; adapted from Ryzhkov et al. (1998, JAM)
Polarimetric Radar Signatures in the Stratiform Bright-band

Zdr maxima below Zh bright band, associated with wet, melting snow flakes.

The wet wobbling snow flakes cause LDR to increase in the melting zone.

$\rho_{hv}$ is a minimum due to assortment of particle axis ratios, canting angles, and sizes in the melt zone.

Fig. 7.74. Range–height indicator (RHI) scan data using the CSU–CHILL radar depicting $Z_h$, $Z_{dr}$, LDR$_{uv}$, and $|\rho_{co}|$ in a stratiform event with some imbedded convection. From Beaver and Bringi (1997, © 1997 IEEE).