PROBLEM SET 3 ANSWERS

1a - WSR-88D BEAM CENTER FOR 1st TILT IS MORE THAN A KM ABOVE TIA AND CAN NOT DETECT SHALLOW MICROBURSTS AS TYPIFIED BY Fig 5.3. However, the radar will detect the precipitation echo for showers AND storms that produce BOTH DRY AND wet microbursts.

1b - IF 0° BEAM CENTER IS to BE AT 80m AGL THEN radar MUST BE ON 80m tower AND BEAM Diameter would be 160m so $R(\sin 0.5°) = 160m$ and $R = 18.3$ Km. BECAUSE we have used simple geometric calculations our results ARE "optimistic." Since radar towers ARE USUALLY 10-25 m tall, SCANNING AT 0° is NOT A GOOD strategy UNLESS RADAR is ON OR VERY NEAR THE AIRPORT.

1c - If we Accept the "typical" wind profile of Fig. 5.3, then 60% of V_{max} CAN be measured at $(3.5)(80m)$ or 280 m. Since tower is 80m tall, them center of the 0.5° tilt MUST BE 200 m ARL (i.e., $\tan 0.5° = \frac{200m}{R}$ OR $R \cong 23$ Km)

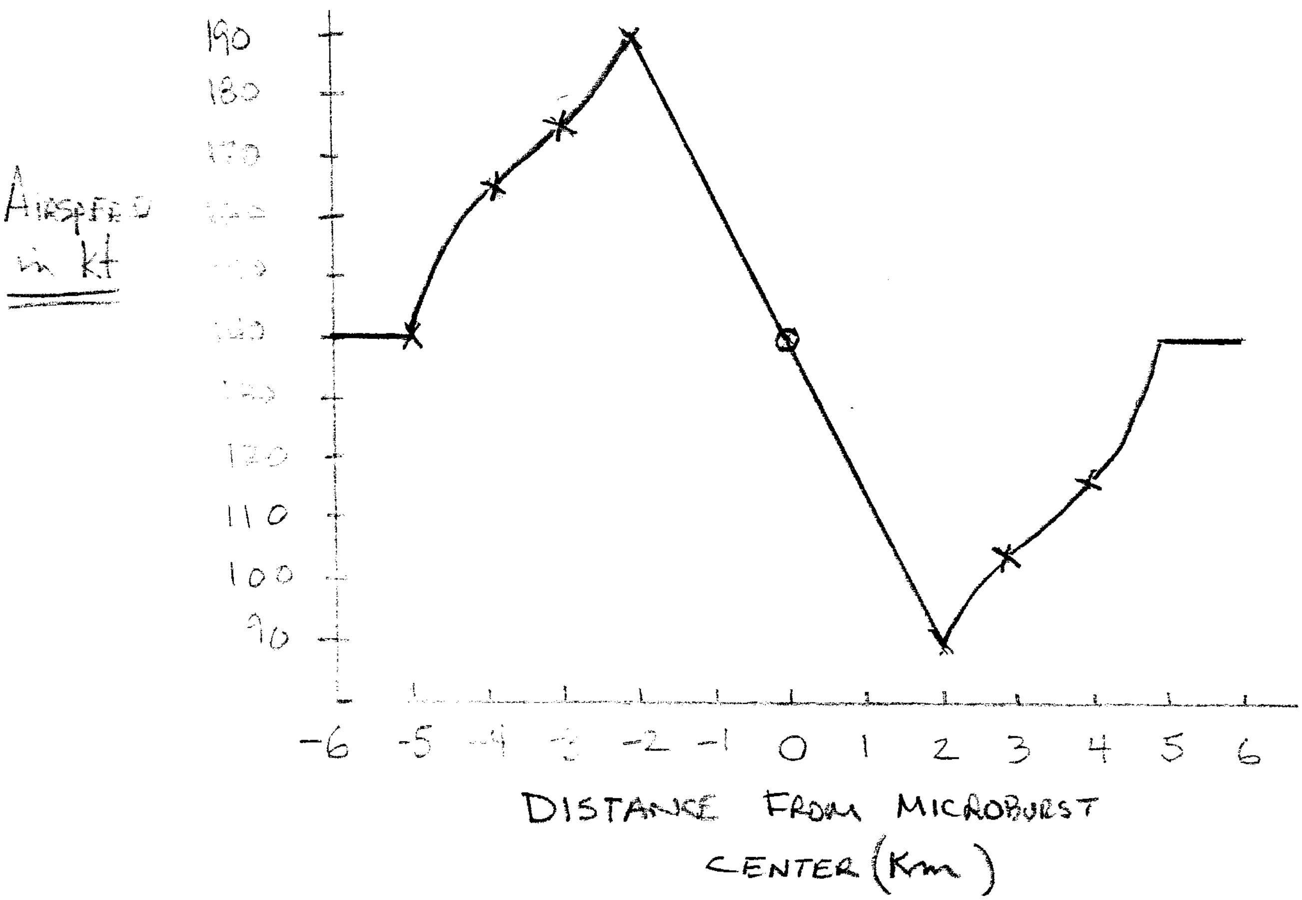
1d - Maximum $\Delta V_r \cong 50$ m/s across distance of 4 Km

So Maximum divergence $\cong \frac{50 m/s}{4 \times 10^3 m} \cong 1.25 \times 10^{-2} s^{-1}$

which is A VERY STRONG VALUE OF DIVERGENCE!

Problem Set 3 Answers

1e - Note: Aircraft ground speed is constant at 140kt (~70 m/s)
Windspeed ≡ 0 beyond 5 km range from microburst center



Aircraft loses ~ 100 kt of air speed across a distance of 4 Km or ~50 m/s

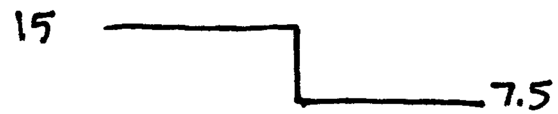
Since groundspeed is constant at ~70 m/s each km on the plot ≅ 14.3 s, so loss of 100 kt in airspeed occurs in about 57 s !

PROBLEM SET 3 ANSWERS

2-a Max outbound V_r is at 135° AND is 15 m/s
Max inbound V_r is at 315° AND is 7.5 m/s

THUS, WIND DIRECTION EVERYWHERE IS FROM 315°
blowing toward 135° or NW

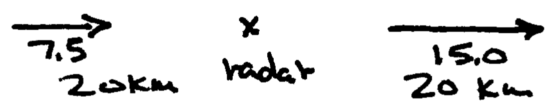
2-b 2-D HORIZONTAL WIND SPEED is 15 m/s EVERYWHERE NW of radar and 7.5 m/s Everywhere SE of radar BUT problem setup leads to discontinuity ALONG line from 45° to 225° where speed goes as



So

45° = indeterminate BUT 11.25 m/s would be good guess
90° = 15 m/s (Note if you calculated using cos AND my imperfectly drawn curve answer is less than 15)
225° = SAME AS 45°
315° = 7.5 m/s

2-c MAX V_r difference across 20 km radius is 7.5 m/s as per



$$\text{Div} = \frac{7.5\ \text{m/s}}{4 \times 10^{4}\ \text{m}}$$

$$\text{Div} = 1.875 \times 10^{-4}\ s^{-1}$$

PROBLEM SET 3 ANSWERS

2-d The total AREA divergence CAN BE OBTAINED by estimating THE difference in the areas under the inbound and outbound curves AND dividing by diameter of sampling circle - this gives

$$15\,m/s \,/\, \pi\, 4\times10^4\, m \cong 1.2\times10^{-4}\, s^{-1}$$

BUT EVERYONE evaluated the integrals

$$\int_0^{180^\circ} 15 \sin\theta\, d\theta + \int_{180^\circ}^{0^\circ} -7.5 \sin\theta\, d\theta$$

or some variant, which gives SAME ANSWER AS ABOVE — AS LONG AS you kept the signs straight.

Would we expect rising OR SINKING VERTICAL MOTIONS OVER THE RADAR? How strong?

PROBLEM SET 3 ANSWERS

3a - Using the M-P paper you begin with

$$Z = \sum N_D D^6 \delta D$$ substitute from eq. 1

$$Z = \sum N_0 e^{-\Lambda D} D^6 \delta D$$ using eq. 2 for N_0 and

integrating across all drop sizes 0 to ∞ gives

$$Z = N_0 \int_0^\infty e^{-\Lambda D} D^6 \, dD$$ which can be

solved by integration by parts OR by using integral tables – the eventual bottom line is that

$$Z = 6! N_0 / \Lambda^7$$ doing the arithmetic

AND keeping units straight INDEED gives $Z = 296 R^{1.4}$, the famous M-P Z-R relation

3b - M-P Assumptions PLUS Basic Radar Assumptions

* WATER DROPS
  Spherical DROPS
* Rayleigh SCATTERERS ($\lambda = 10$ cm)
* BEAM Volume FILLED
  Scatters uniformly DISTRIBUTED
  NO ATTENUATION

Basic in Paper

VERTICAL VEL $\equiv 0$

$N_0 \equiv 0.08 \text{ cm}^{-4}$ for Any intensity rain

Drop size dist depends ONLY ON rain rate (eq. 3)

continuous drop size distribution

* IGNORE VERY SMALL drop effects (< 1.5 mm D)

Drops in continual danger of disintegrating (?)

3c - See above *

PROBLEM SET 3 ANSWERS

4-a CAN use 11.5 from BRANDES AN Wilson WRITTEN AS A SUMMATION

$$R = \frac{\pi \rho}{6} \sum_{i=1}^{6} D_i^3 \, V_{t_i} \, N(D_i)$$

SETTING All this up in A TABLE FOR STILL AIR I SUMMED the 6 drop diameters to get

$$2468 \times 10^{-7} \frac{g}{cm^3} \; cm^3 \; \frac{cm}{s} \; \frac{1}{cm^3} = 2468 \times 10^{-7} \frac{g}{cm^2} s^{-1}$$

need to get this in mm/hr so multiple by 3600 s/hr to get

8.9 mm/hr OR ×10 89 mm/hr
① ②

for −4 m/s vertical velocity add VV to V_t for each drop size AND redo arithmetic to get 1) 20.3 mm/hr or 2) 203 mm/hr WOW!

for +3 m/s vertical velocity redo the arithmetic for VV + V_t ONLY for the 5 mm drops

SINCE THESE ARE ONLY SIZE THAT CAN FALL AS RAIN

1) 2.4 mm/hr or 2) 24 mm/hr

Problem Set 3 Answers

4-b Must first sum D^6 for our drop size distribution

This gives a) $86071 \frac{mm^6}{m^3}$ or 2) $860710 \frac{mm^6}{m^3}$

49 dBZ 59 dBZ (→53 dBZ)

for 88D Convective Z-R $Z = 300 R^{1.4}$ result is

$(86071/300)^{1/1.4} = R$ $R = 57\ mm/hr$ or for

2) $R = 104\ mm/hr$

4-c for cool season west Z-R

$Z = 75 R^{2.0}$

we get 1) 34 mm/hr or 2) 52 mm/hr

PROBLEM Set 3 ANSWERS

4-d REASONS for differences between "actual" rates AND radar Z-R derived rates

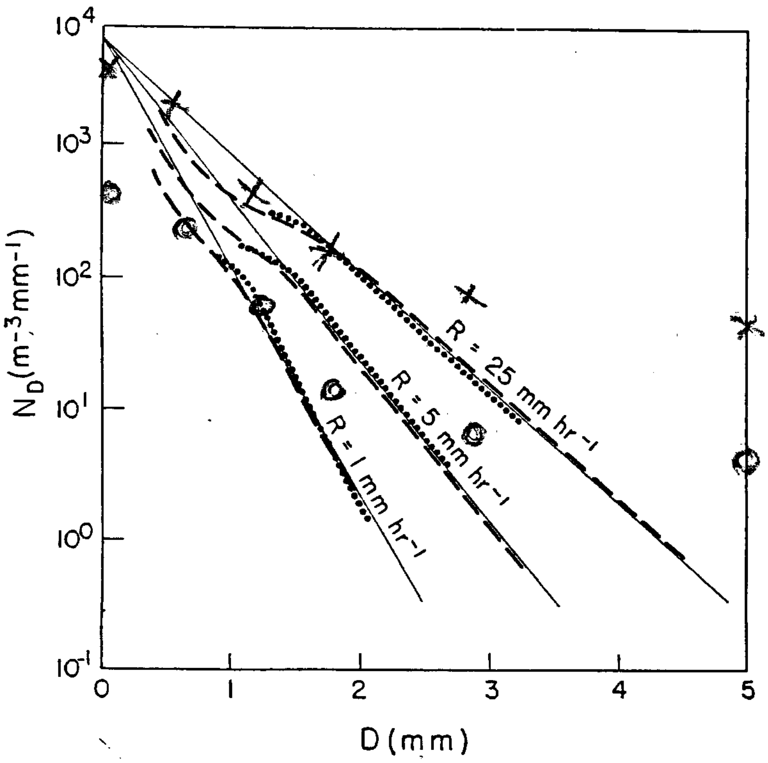
Our drop size distribution is MUCH different than M-P distributions – thus Z-Rs close to M-P should NOT give GOOD RESULTS

For $Z = 300R^{1.4}$ our drop distribution is obviously quite different than the ONE inherent to this Z-R

For $Z = 75R^{2.0}$ SAME AS ABOVE, PLUS this is A STRATIFORM Z-R AND our storm is definitely convective

VERTICAL VELOCITIES ESSENTIALLY DESTROY the ZR relationships

Our storm is either 1) fairly typical shower OR 2) A CATS AND Dogs DOWNPOUR



FINALLY – the EFFECT of high NUMBERS of medium to large size drops HAS huge impacts ON the ACTUAL RAINRATE

PROBLEM SET 3 ANSWERS

5-a from GREENE & CLARK

$$VIL \equiv M^* = 3.44 \times 10^{-6} \int_{h_{BASE}}^{h_{TOP}} Z^{4/7} \, dh' \quad (8)$$

Assumptions – ESSENTIALLY SAME AS M-P question 3b BUT

they have also assumed the echo is WELL-SAMPLED BY radar AND they have NOT ASSUMed spherical water drop RAYLEIGH SCATTERS

5-b VIL implies vertical integration of water mixing ratio BUT eq 8 yields A vertical integration of Z_e, the "effective" radar reflectivity factor

5-c Since the reflectivity in the first (hybrid) tilt are extrapolated downward to the RADAR ELEVATION, the following CAN often happen in western U.S.:

1) a storm at long range with base is sampled well above radar elevation – there may be only virga or weak Z below the tilt, thus VIL too high OR if there is heavy precip below 1st tilt VIL too Low – BEAM blockage increases the elevation of the hybrid bin, acerbating this problem. Note this problem is NOT UNIQUE TO THE WEST.

Problem Set 3 Answers

5-c 2) A storm located near the radar has high dBZ to the surface but is over terrain much lower than radar elevation (as per Tucson radar sampling a heavy storm over TIA) VIL too low.

3) A storm located near the radar has high dBZ to the surface BUT IS OVER A PEAK with much higher elevation than the radar – VIL calculation extrapolates downward into the mountain (as per Tucson radar sampling a heavy storm over top of CATALINAS) VIL TOO HIGH

5-d VIL DENSITY NORMALIZES VIL TO THE STORM TOP HEIGHT SO THAT STORMS OF Different character AND Different vertical extents CAN BE MORE DIRECTLY COMPARED

5-e Cycles of high & low VIL values in VCP-21 result from the large vertical gaps at higher elevation tilts – depending on range upper portions of storm MAY NOT BE sampled

Cone of silence results in poor sample AND low VIL CLOSE to RADAR – UNAVOIDABLE unless data from other RADARS ARE USED

How can VCP-21 VIL at 28 km range exceed VCP-11 by 20 kg/m² – After much analysis I don't think it CAN!