A Wind Shear Hazard Index

1 Learning Objectives

- Students will learn about microburst phenomenology.
- Students will learn why microbursts pose a hazard to aviation.
- Students will learn about hazard assessment calculation.

2 Introduction

Low level wind shear (a sudden change in either the speed or direction of the wind) is recognized as a severe flight hazard. An aircraft exposed to wind shear of sufficient intensity and duration, may lose flight performance with a critical reduction of airspeed or flight altitude. A microburst in connection with this strong wind shear sometimes causes serious problems for either landing or departing aircraft, since the aircraft are at low altitudes and traveling at just over 25 % above stall speed. The typical scenario for an aircraft encountering a microburst on approach is shown in figure 1. A strong downdraft spreads out as the air nears the ground. The aircraft initially speeds up to increase the headwind, and the increased lift causes it to rise above its intended flight path. Sensing that, the pilot may reduce thrust to get back to the intended flight path. But, when the aircraft enters the core of the microburst, tail wind and downdraft reduce its air speed and push the aircraft toward the ground.

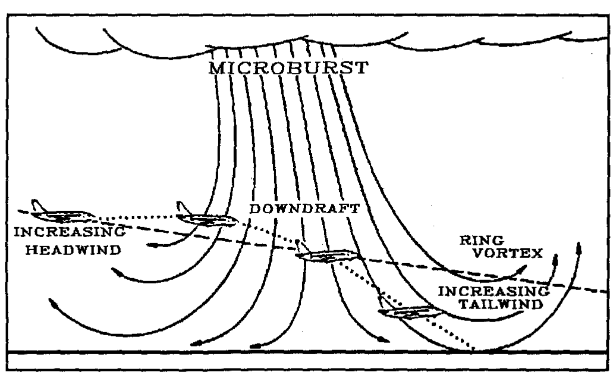


Figure 1. Schematic of an aircraft microburst encounter (Vicroy, NASA technical paper 2827, 1988)

In order to characterize this hazard, a nondimensional index, known as the F-factor was developed based on aerodynamic principals and understanding of wind shear phenomena as

$$F \equiv \frac{dV}{dt}\frac{1}{g} - \frac{w}{V_a}$$

where dV/dt is the shear term—the time rate of change of V experienced by the aircraft, g is gravitational acceleration, w is the updraft, and V_a is air speed. Assuming conservation of mass, the F-factor is rewritten as follows:

$$F_{Hor} = Shear\frac{V_g}{g}$$

$$F_{Vert} = 2F_{Hor}\frac{gh}{V_a V_g}$$

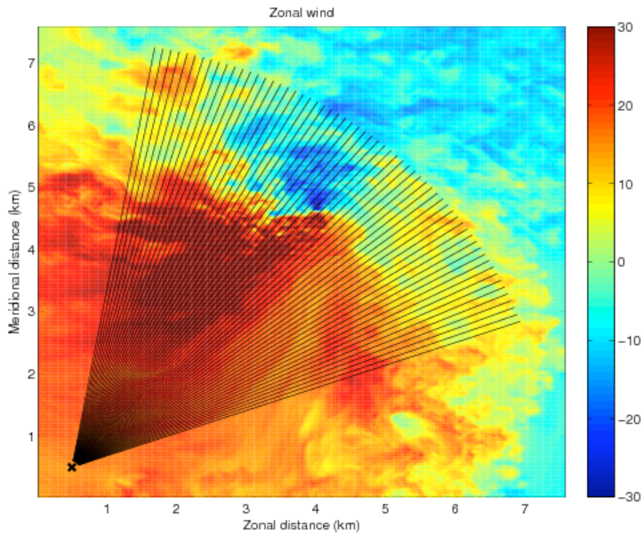
$$F_{Total} = F_{Hor} + F_{Vert}$$

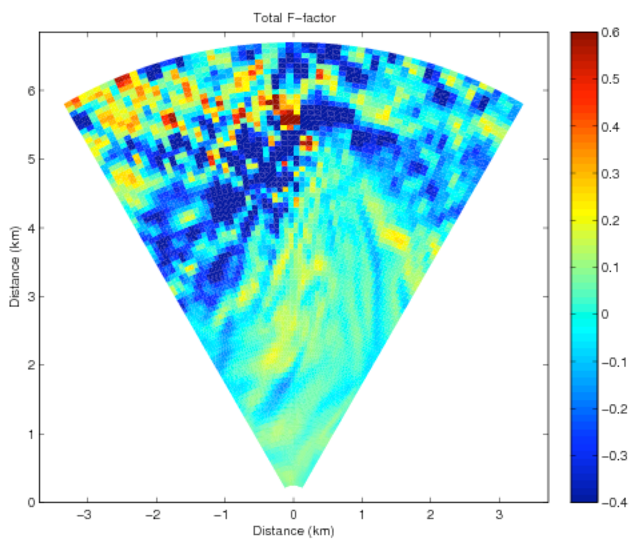
where Shear = dV/dR (R is along the flight path), V_g is aircraft ground speed, h is altitude. It is suggested to use these equations for the following hands-on activities.

3 Hands-On Activities

1. Acquire the wind field data (mat format) from the following website. http://arrc.ou.edu/radar/Wind_data.mat
   You can use the Matlab command load filename to pull the data into the Matlab environment. After the loading data, you can use the data DAT.u (z, x, y) and DAT.v (z, x, y) for zonal and meridional winds, respectively. Each data set has dimensions of 83x303x303 with 25 m mesh grid in the horizontal. You can use the command ARPS.BASE.zp (not a Matlab command) to know the height (km) of each level. Plot the U and V fields at 300 m height (corresponds to z=14 of the data) referring to the attached sample program.
2. Assume aircraft mounted airborne Doppler radar on the nose flies in the wind field in Prob. 1. The radar scans -30 to 30 degrees in azimuth angles at intervals of 1 degree, and 100 to 6850 m in range gates at intervals of 75 m gate width. The Radar beam is assumed to be pencil one. Add the Radar coverage on the figures of Prob.1. Set the position and heading angle of the aircraft appropriately.
3. Calculate and plot shear of the radial velocity along the range gate for the Radar coverage you set in Prob. 2. You should use the least squares method with 5 data points for the shear calculation. You can use Matlab command polyfit (, , 1).
4. Calculate and Plot F_{Hor}, F_{Vert}, F_{Total}. Assume the air speed of the aircraft is 50 m/s.

   The following figures are example plots from the file Wind_data.mat.



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%
% Sample program to plot wind fields and calculate F-factor
%
clear
load Wind_data; % Load wind data

z = 14; % set z = 14 corresponds to 300 meters

X = repmat([1:303]*25,[303 1]); % DATA has 25 m mesh grid
Y = repmat([1:303]'*25, [1 303]);
U = squeeze(double(DAT.u(z,:,:))); % Zonal wind
V = squeeze(double(DAT.v(z,:,:))); % Meridional wind
```

```
figure;
pcolor(X/1000,Y/1000,U); % Plot zonal wind
shading flat;
title('Zonal wind');
xlabel('Zonal distance (km)');
ylabel('Meridional distance (km)');
colorbar;
caxis([-30 30]);
ofile = sprintf('zonal');
print ('-dpdf','-painter', ofile); % Save pdf file

figure;
pcolor(X/1000,Y/1000,V); % Plot meridional wind
shading flat;
title('Meridional wind');
xlabel('Zonal distance (km)');
ylabel('Meridional distance (km)');
colorbar;
caxis([-30 30]);
ofile = sprintf('meridional');
print ('-dpdf','-painter', ofile); % Save pdf file

rx = 10; % Set radar position (meter)
ry = 10; %
if mod(rx,25)~=0
   rx=floor(rx/25)*25;  % rx must be 25*integer(data grid)
end
if mod(ry,25)~=0
   ry=floor(ry/25)*25;  % ry must be 25*integer(data grid)
end
hdg = 40;              % Heading of the aircraft (degree)
va = 50;       % Air speed of the aircraft (m/s)
range_m = 100;         % Range from radar to first gate (meter)
delr = 75;                    % Gate width (meter)
num_gates = 90;         %  Number of gates
R = [range_m:delr:range_m + num_gates*delr];
AZ = [-30:30];          % Azimuth degree
theta = repmat(AZ'+hdg,[1 length(R)])*pi/180;

X_r = rx + repmat(R,[length(AZ) 1]).*sin(theta); % Radar coverage
Y_r = ry + repmat(R,[length(AZ) 1]).*cos(theta); % Radar coverage
U_r = interp2(X,Y,squeeze(double(DAT.u(z,:,:))),X_r,Y_r);
V_r = interp2(X,Y,squeeze(double(DAT.v(z,:,:))),X_r,Y_r);
```

```
Vr = U_r.*sin(theta) + V_r.*cos(theta); % Radial wind in the Radar coverage
% Vr is AZxR matrix
% You need to add code to calculate parameters.
h= 300; % Height (meter)
Shear = ?????;
Vg =  ????; % Ground speed
F_hor =  ?????;
F_vert =  ?????;
F_tot =  ?????;
```

Reference

Vicroy, D. D., “Influence of Wind Shear on the Aerodynamic Characteristics of Airplanes”, NASA Technical Paper 2827,DOT/FAA/PS-88/15, 1988,61pp