MET 4410 Remote Sensing: Radar and Satellite Meteorology
MET 5412 Remote Sensing in Meteorology

Lecture 15 Part2 Slides: Doppler Dilemma, Range and Velocity Folding, and Interpreting Doppler velocity patterns

Doppler Dilemma

- If we want to have a large V_{max} , we must have a smaller r_{max}, vice versa.
- Both V_{max} and r_{max} depend on PRF. V_{max} also depends on wavelength, but r_{max} does not.
- For a S-band (10 cm) radar, if the PRF is 1000 Hz, the maximum unambiguous range (r_{max}) is 150 km while V_{max} is ±25 m/s. For a X-band (3-cm) radar using the same PRF, r_{max} is still 150 km but V_{max} is ±8 m/s.
- In meteorological situations, we prefer to measuring velocities as large as ±50 m/s out to range beyond 200km, so neither S-band or X-band is adequate.

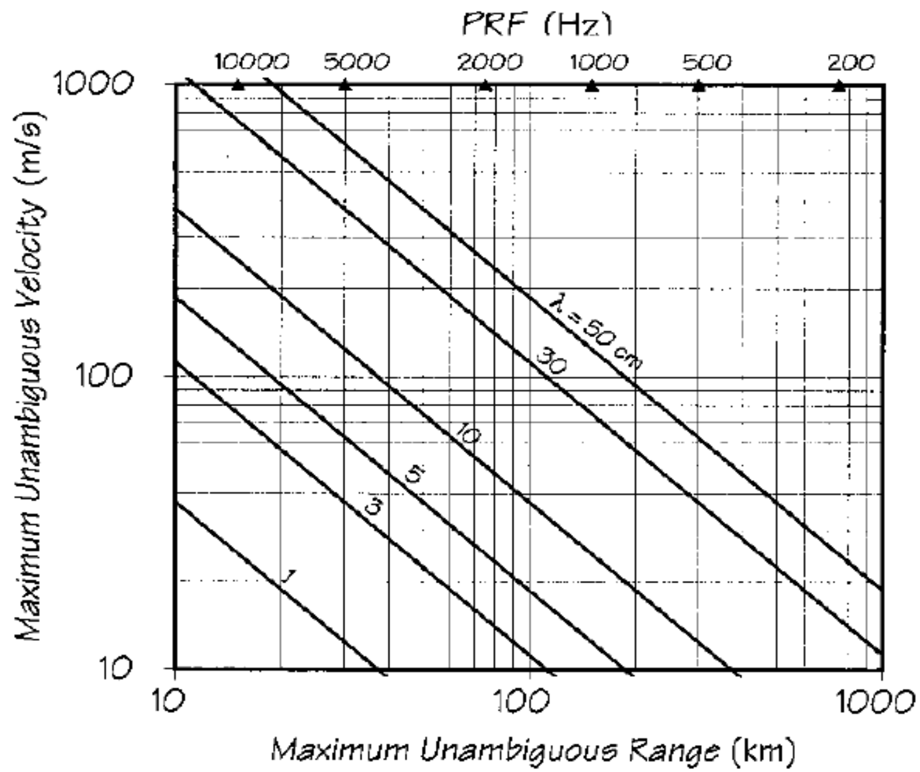


Figure 6.4 Summary of conditions for range and velocity folding (i.e., the Doppler dilemma).

Range Folding (or Ambiguities or Aliasing)

- **Range folding** occurs because the radar doesn't wait long enough between transmitted pulses. That is, the radar transmits pulses too close together to give one pulse enough time to cover the distance between the radar and some storms before the radar sends out the next pulse.
- For example, there is a storm at range r beyond r_{max}. A ***first*** pulse can go beyond r_{max} and detects this storm, but the radar does not know the signal is from the first pulse (now beyond r_{max}), but thinks it is from the ***second*** pulse and displays it at a distance of ($r - r_{max}$).
- **Second-trip or Multi-trip Echoes:** echoes that are displayed in the wrong range interval. If the PRF is high enough and distant echoes are tall and strong enough, sometimes ***third*** or even ***fourth*** trip echoes can be detected.

Range Folding and Multitrip Echoes

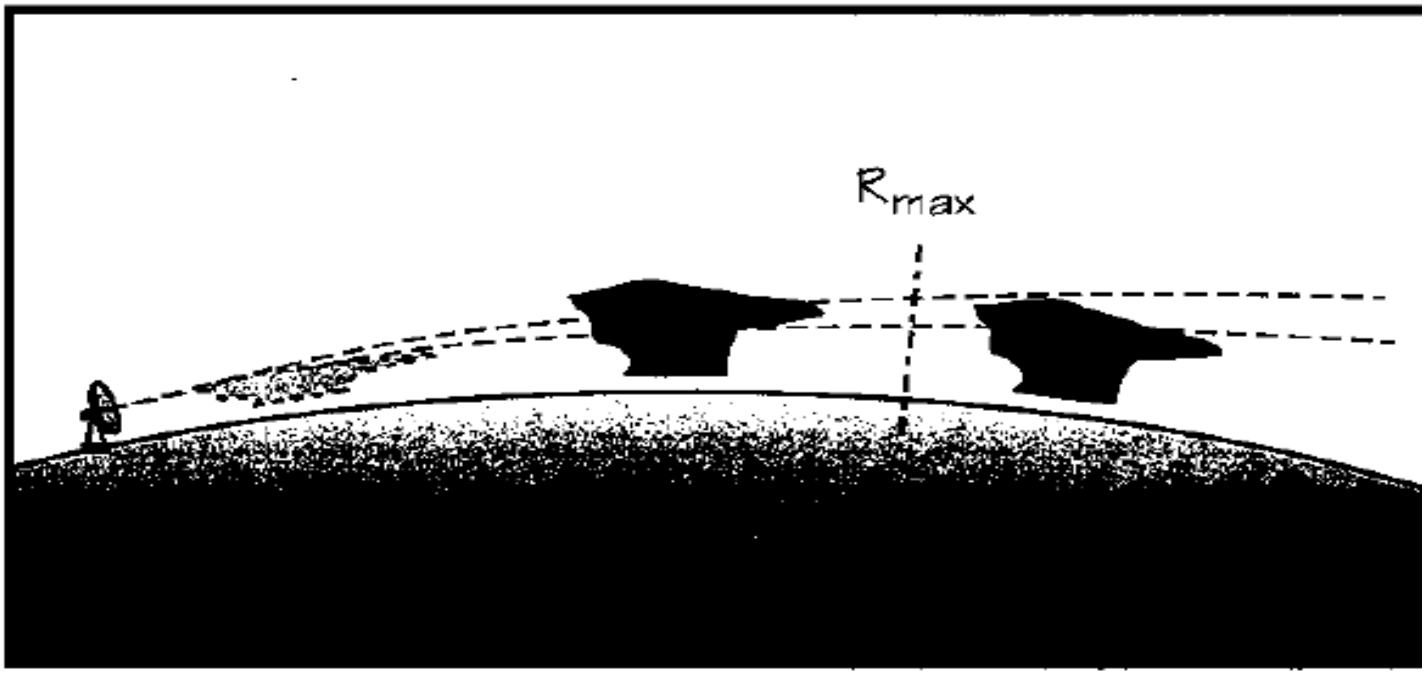


Figure 6.5a Illustration of how a storm beyond r_{max} can be displayed at the wrong range. Two real echoes exist. The first is less than r_{max} away and is displayed at the correct range. The second is beyond r_{max}; it is displayed at a range of $(r - r_{max})$. The faint, dashed storm near the radar is where the radar would display the distant storm.

Recognizing Multitrip Echoes

- Look outside if you are at the local radar station in real time (this is usually impossible)
- By echo shape: narrow, wedge-like echoes are suspicious.

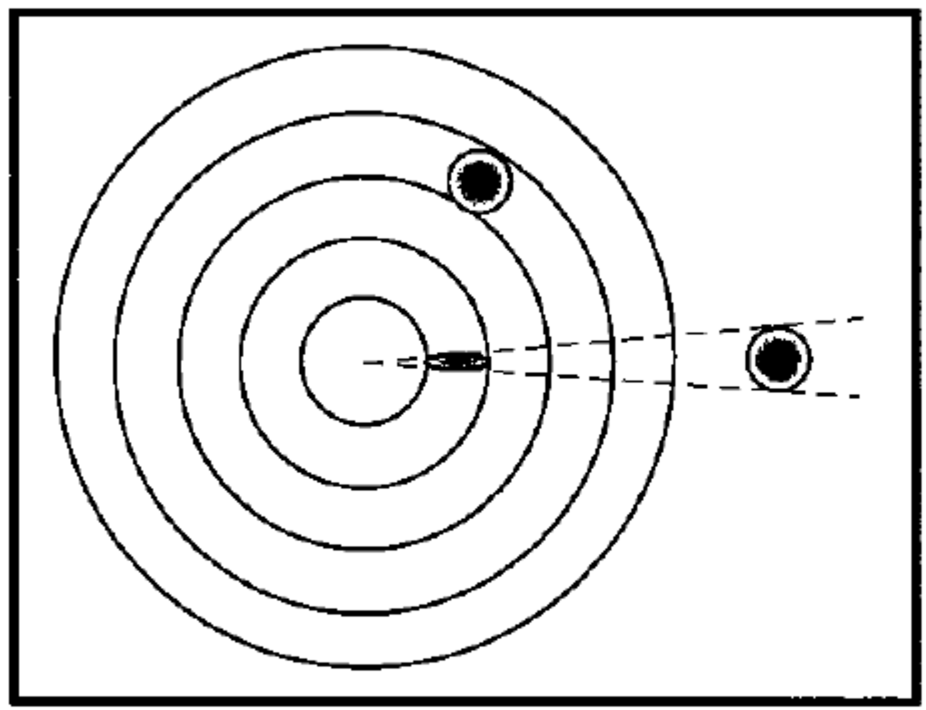
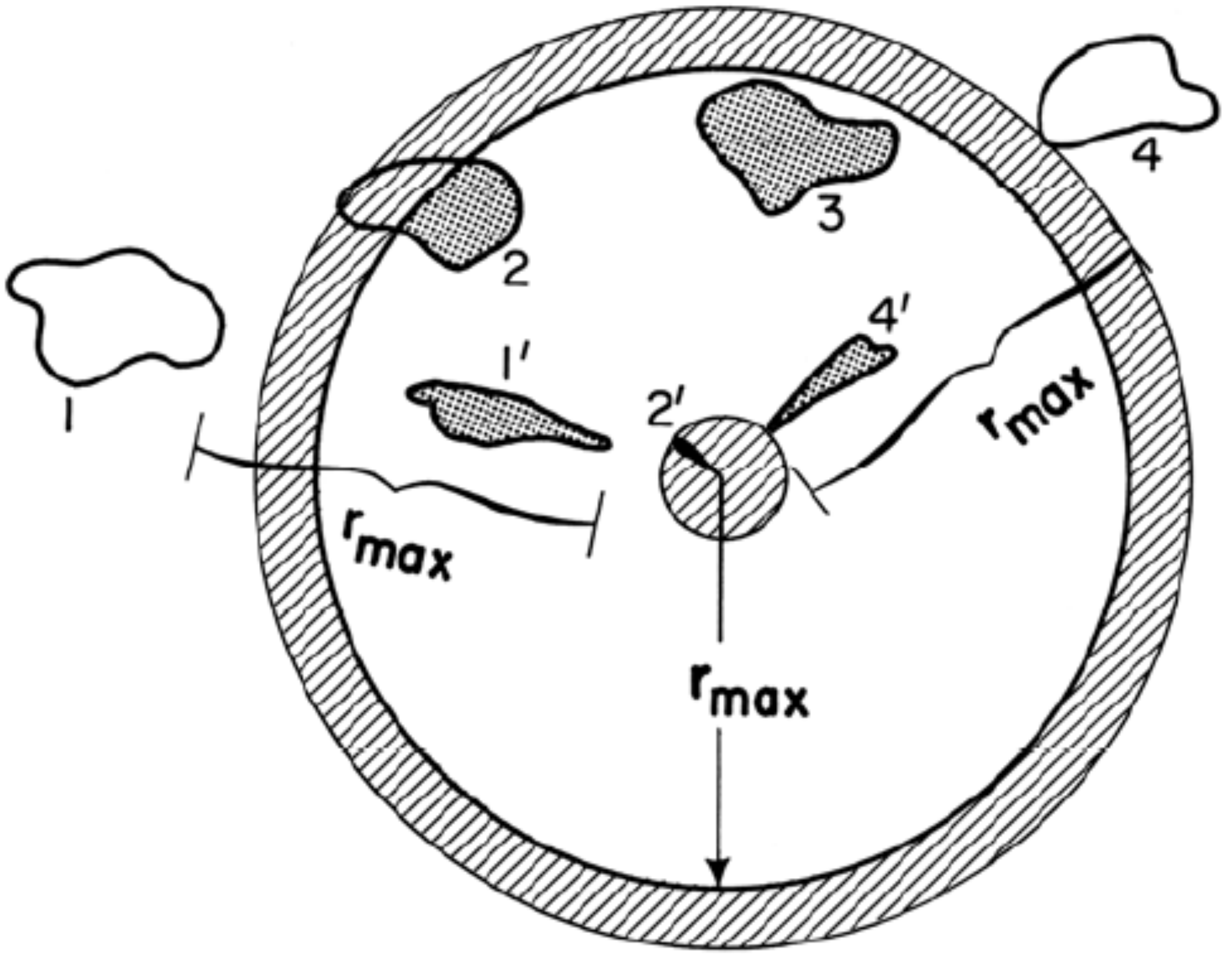


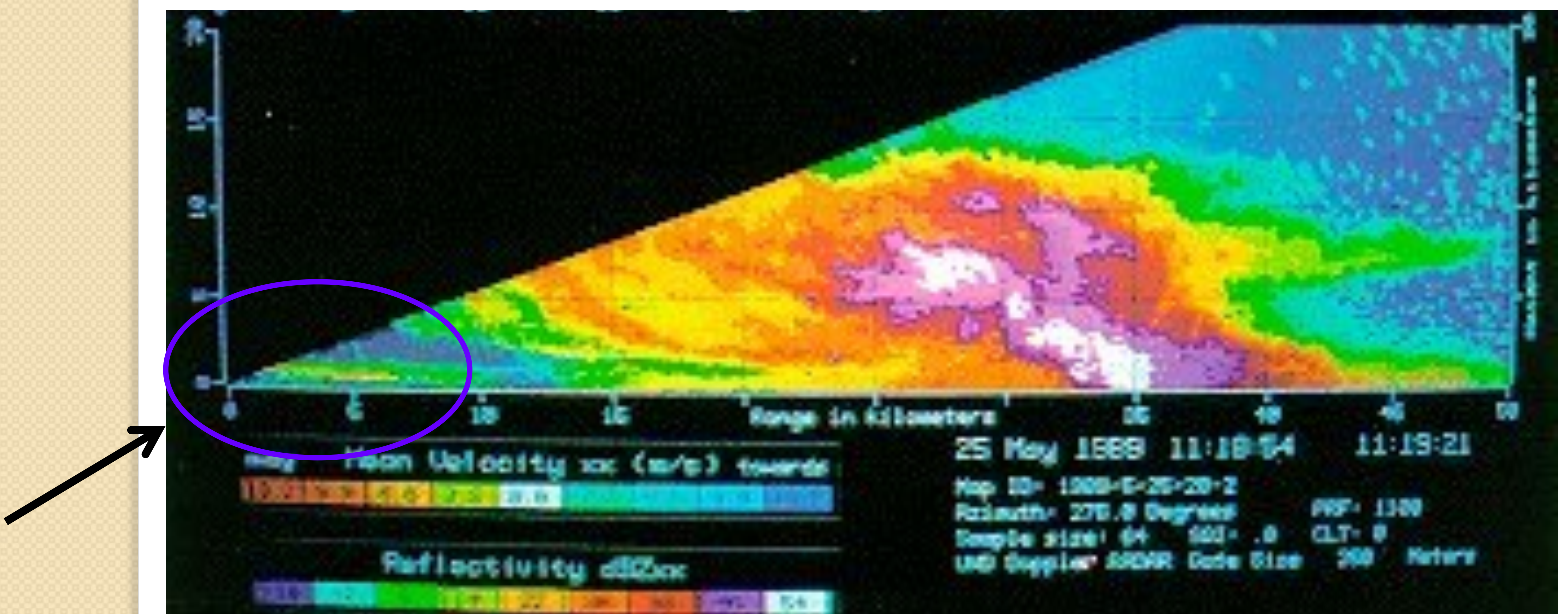
Figure 6.5b Simulated PPI display showing

Image of Multi-trip Echoes (echo#1, #4 and part of #2)



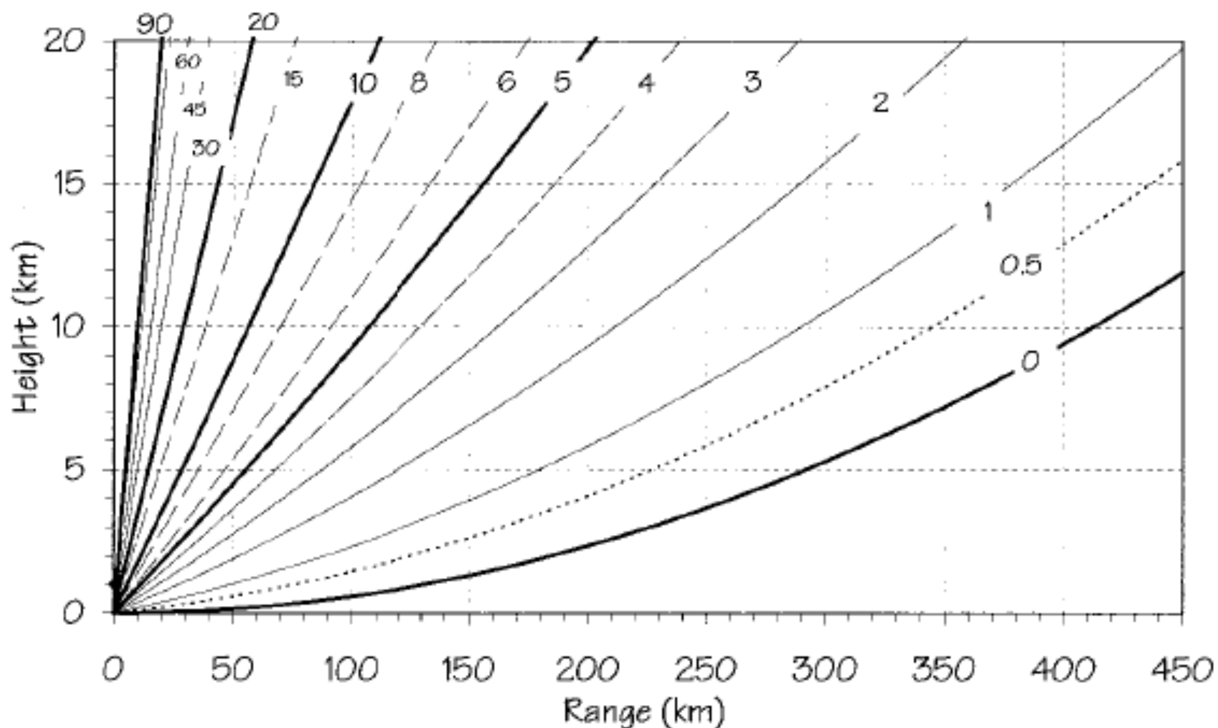
Recognizing Multitrip Echoes (Cont.)

- For any convective-like echo (reflectivity as high as ~40 dBZ) , look at the echo height displayed by RHI. If the height is too small, you can suspect second-trip echo.



Why?

- --A real thunderstorm which is 10 km tall at a range of 200km would be detectable at an elevation angle of about 2.2°. If it is a second trip echo, on a radar with a PRF of 1000 Hz, it would be show up at 200 km -150 km = 50 km. If the echo disappears just above 2.2°, its indicated height would only be 2 km. So if you know that this echo is a convective-like echo, this height is too small, so you should know this is range folding.



Recognizing Multitrip Echoes (Cont.)

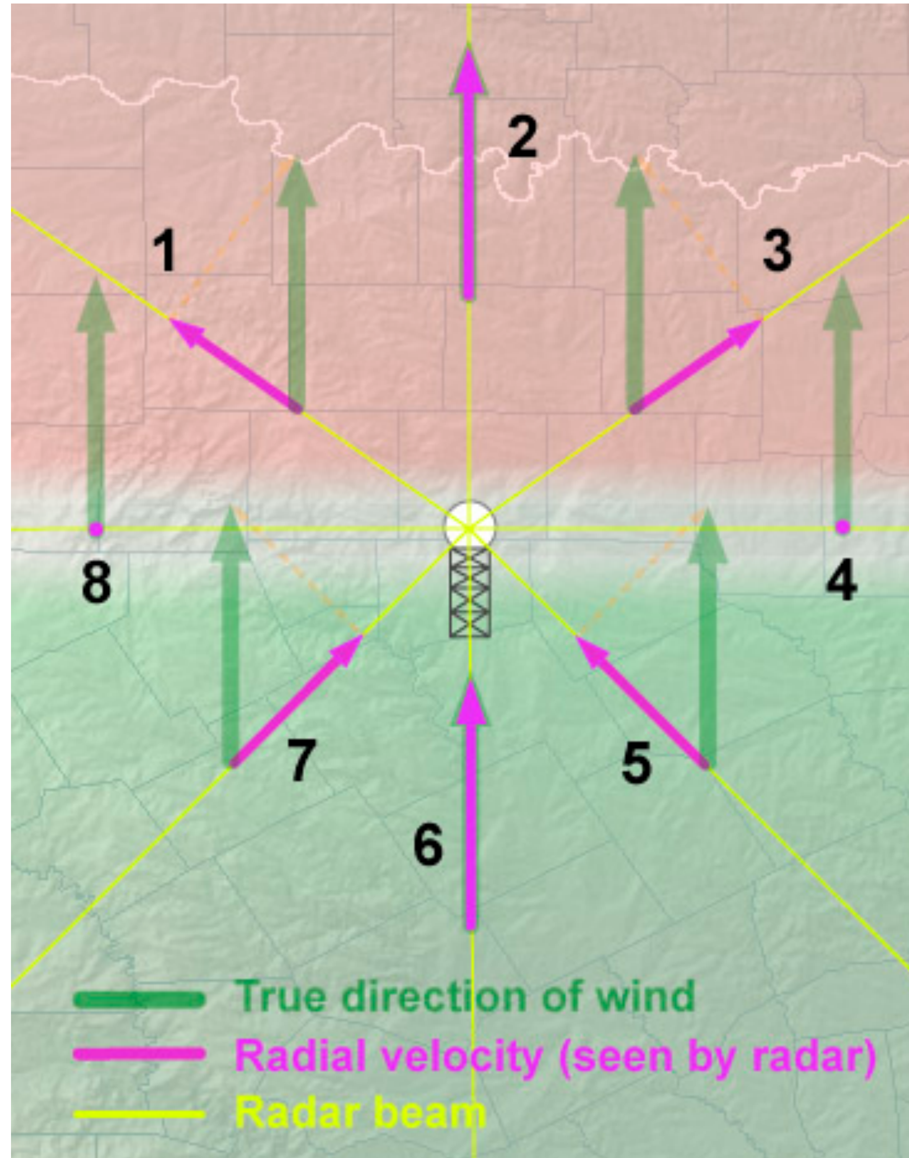
- Multitrip echoes are weaker than real echoes because return power is proportional to $1/r^2$. Low reflectivity(combined with shape and height information) can help differentiate real echoes from multitrip echoes.
- An guaranteed way to determine if echoes are folded or not: ***Change PRF! (This is only for radar operators, not an end user like us)*** After changing PRF, all correct echoes will not change their range but the folded echoes will!

Velocity Folding (or Aliasing)

- **Velocity folding** occurs when the Doppler phase shift is more than ± 180° or ±π radians from the transmitted phase at a given range.
- **How does this appear on a radar display?**

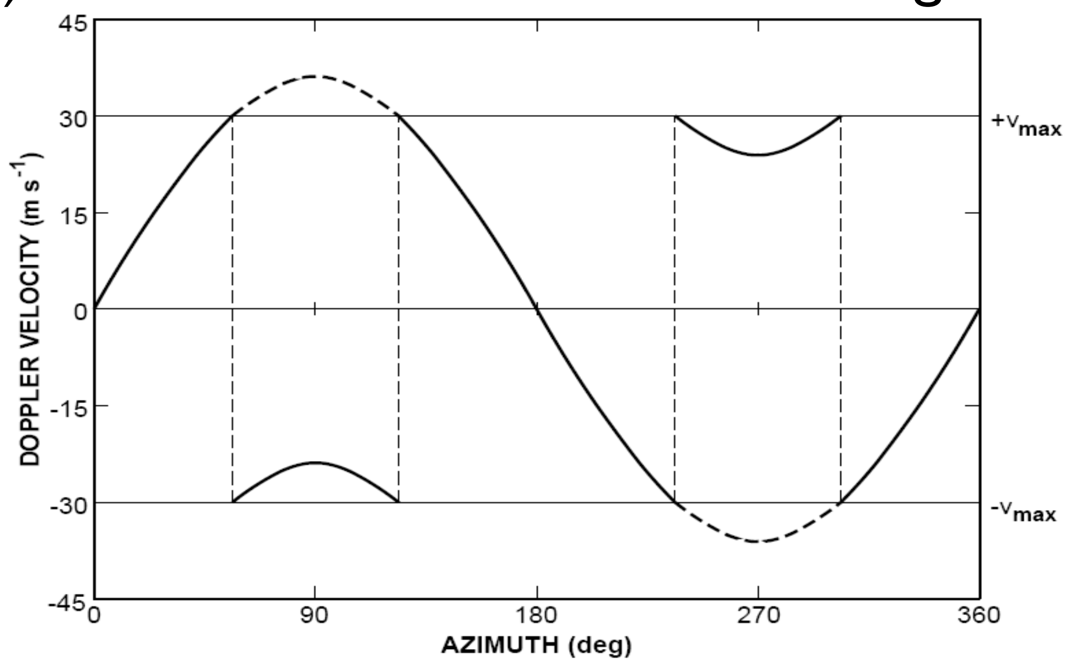
Doppler Radial Velocity

- A Doppler radar can measure winds besides reflectivity. However, it only measures the **Doppler Radial Velocity Vr**, which is the component of the real wind V along the direction of the radar beam.
- **V=Vr*cosα,** where α is the angle between the radar beam and the true direction of wind.
- **Two special cases:** When the radar beam direction is the same as the true direction of wind, V=Vr; when they are perpendicular, Vr=0



Velocity Folding/Aliasing

The figure below shows the measured Doppler radial velocity Vr as a function of the azimuth angle of radar beam relative to the north (0 deg at north) for an environmental wind blowing from the west at 36 m/s.

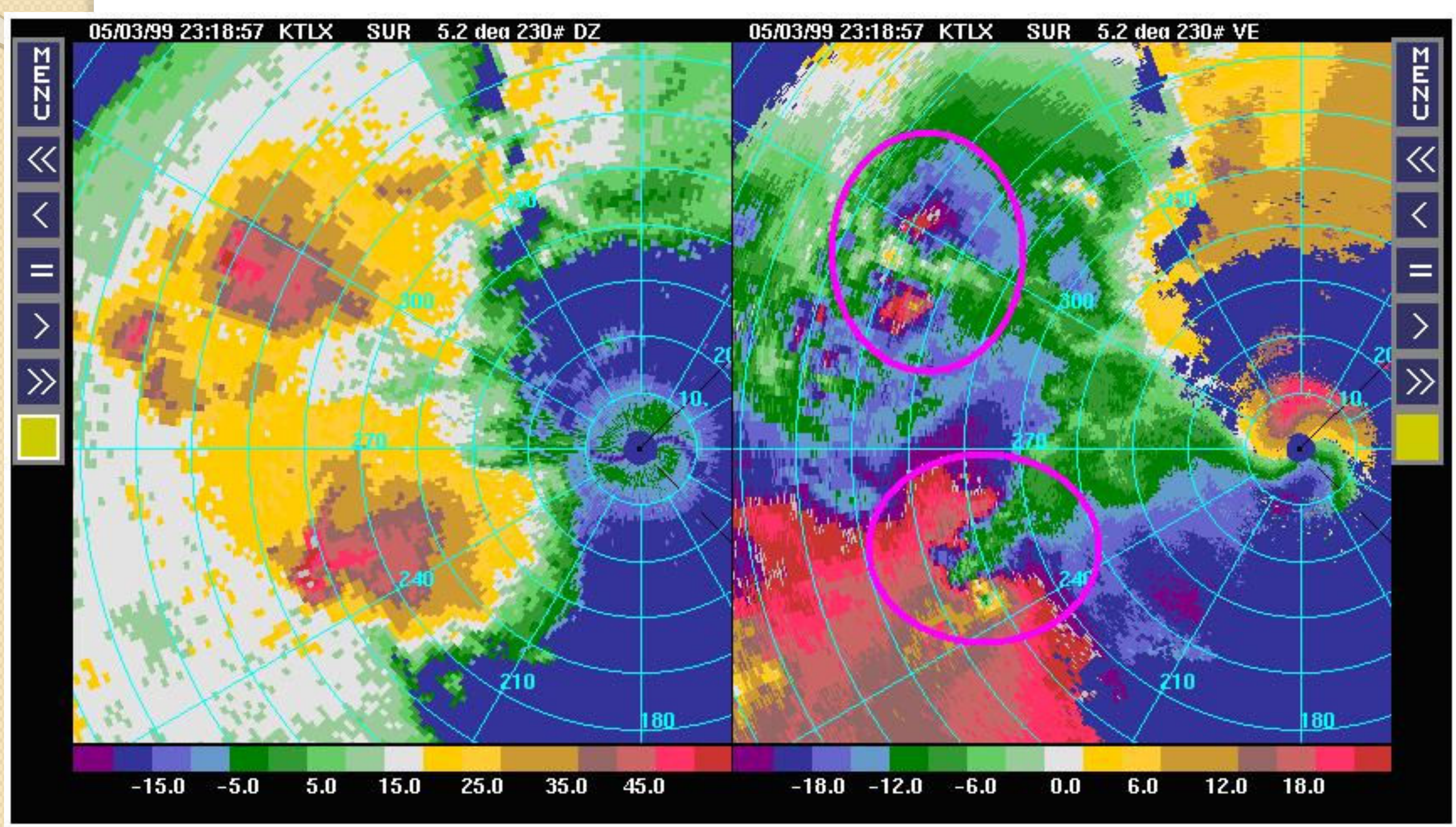


- The aliasing process causes the Doppler velocity values offset by 2 V_{max} (here V_{max} =30 m/s)until they fall within +/- $V_{max.}$ Thus, +36 m/s is aliased to: ***36 m/s -2*30 m/s=-24 m/s***

So $V_r = V_{real} - 2\, V_{max}$ ***or*** $V_{real} = V_r + 2\, V_{max}$

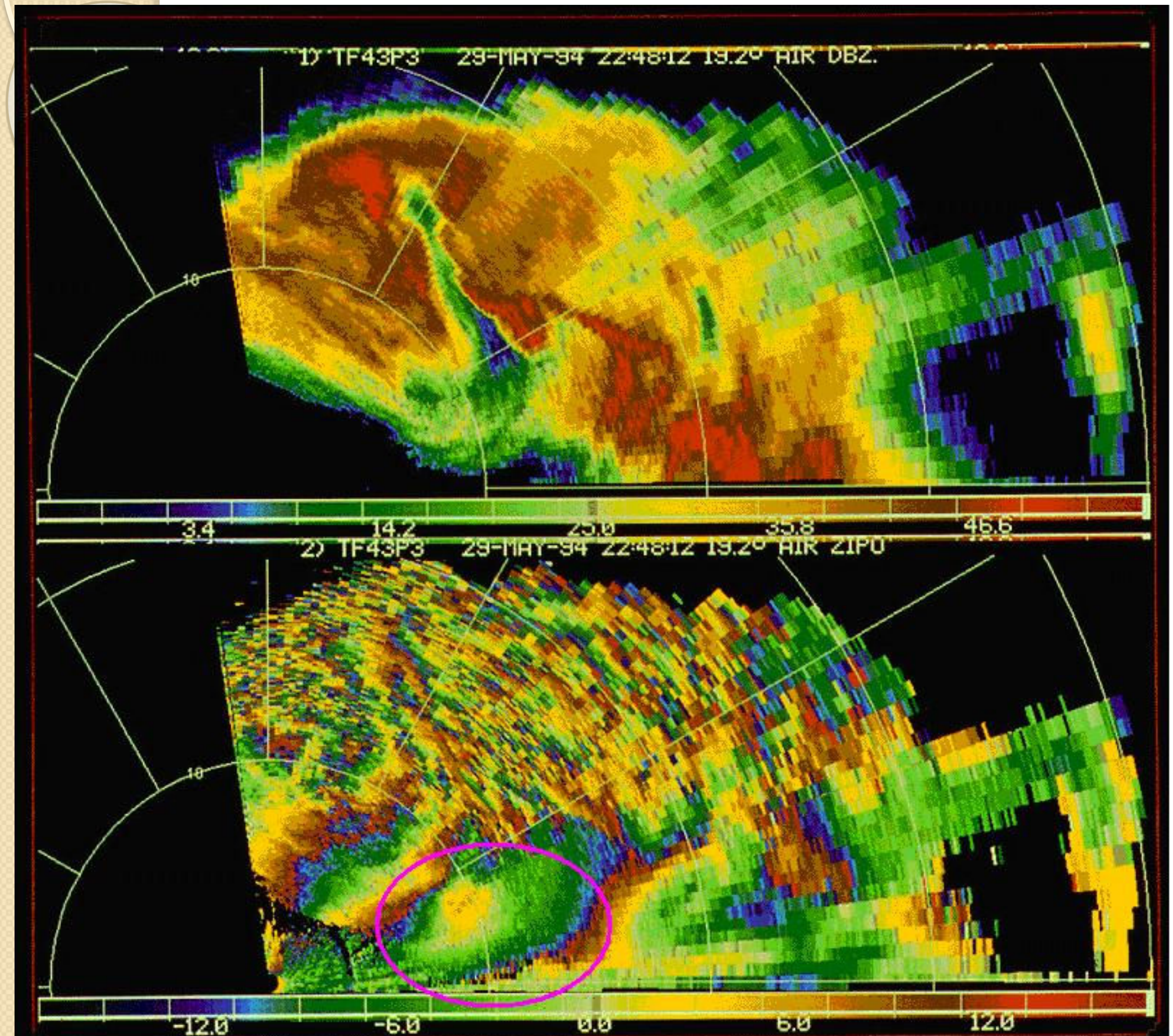
Recognizing Velocity Aliasing/Folding

- Velocity folding is at velocity discontinuity regions(usually in strong reflectivity regions) where Doppler velocity changes from maximum negative values to maximum positive values, or vice versa.



Radar Reflectivity in dBZ **Doppler radial velocity in m/s**

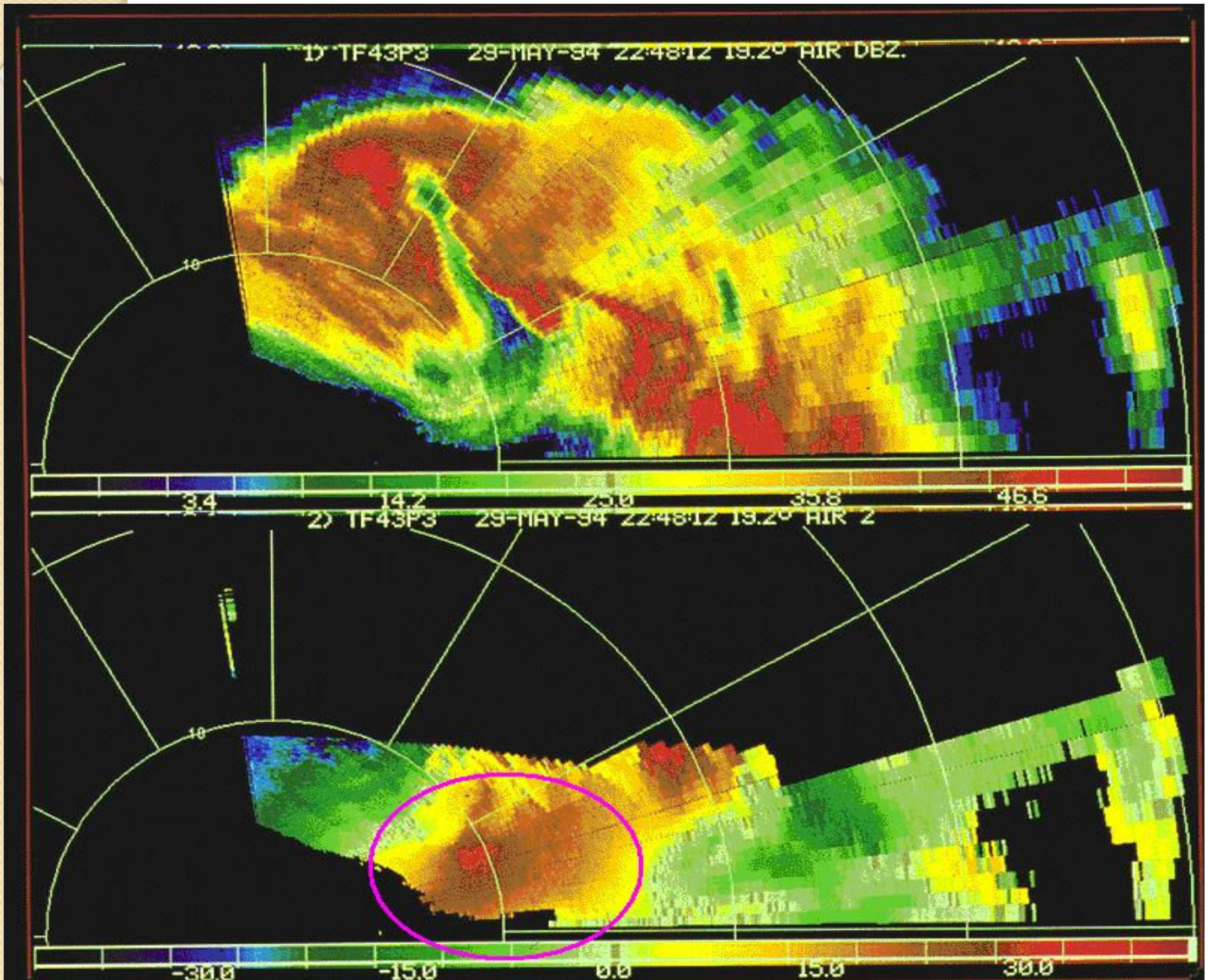
Another Doppler velocity folding case



Reflectivity in dBZ

Doppler radial velocity in m/s

Corrected/Unfolded Doppler Radial Velocity



Reflectivity in dBZ

Unfolded Doppler radial velocity in m/s

Interpretation of Doppler Velocity

Doppler radar viewing configuration (scanning 360 degree at a given elevation angle).

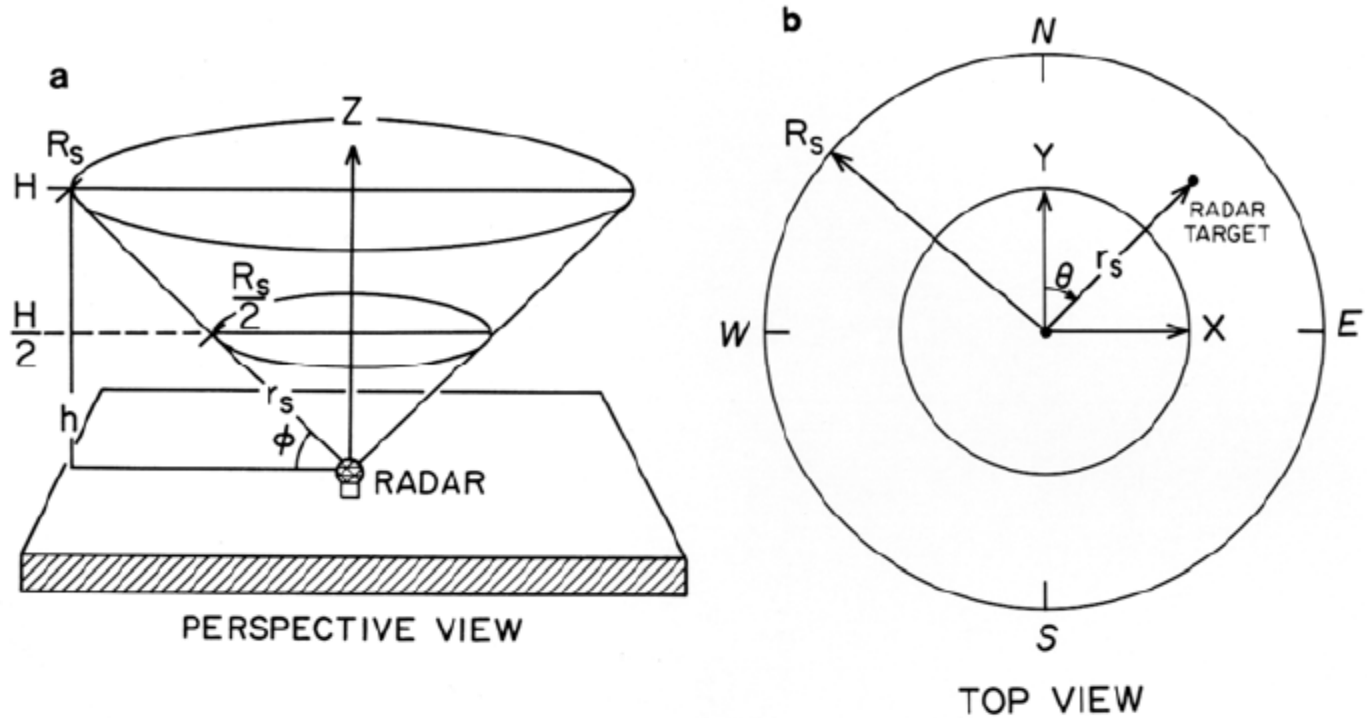


Fig. 2.1.1. Doppler radar viewing configuration. (a) Radar scanning around vertical axis, Z, at a constant elevation angle, ϕ; (b) view of (a) from the top, representing a PPI (plan position indicator) display. R_s is slant range (on conical surface) of the edge of the display corresponding to height H above the ground. The three-dimensional position (x, y, h) of a radar scattering volume ("target") is computed from radar azimuth angle θ, elevation angle ϕ, and slant range r_s.

An Example

- Get wind profile from Doppler radar VAD display
- Doppler velocity is negative for toward radar, positive for away from radar
- Zero value zone means that the wind direction is perpendicular to the radar beam.
- Wind speed at a given height is the maximum value around a constant slant range circle. Wind direction at a given height is determined from the zero value curve.

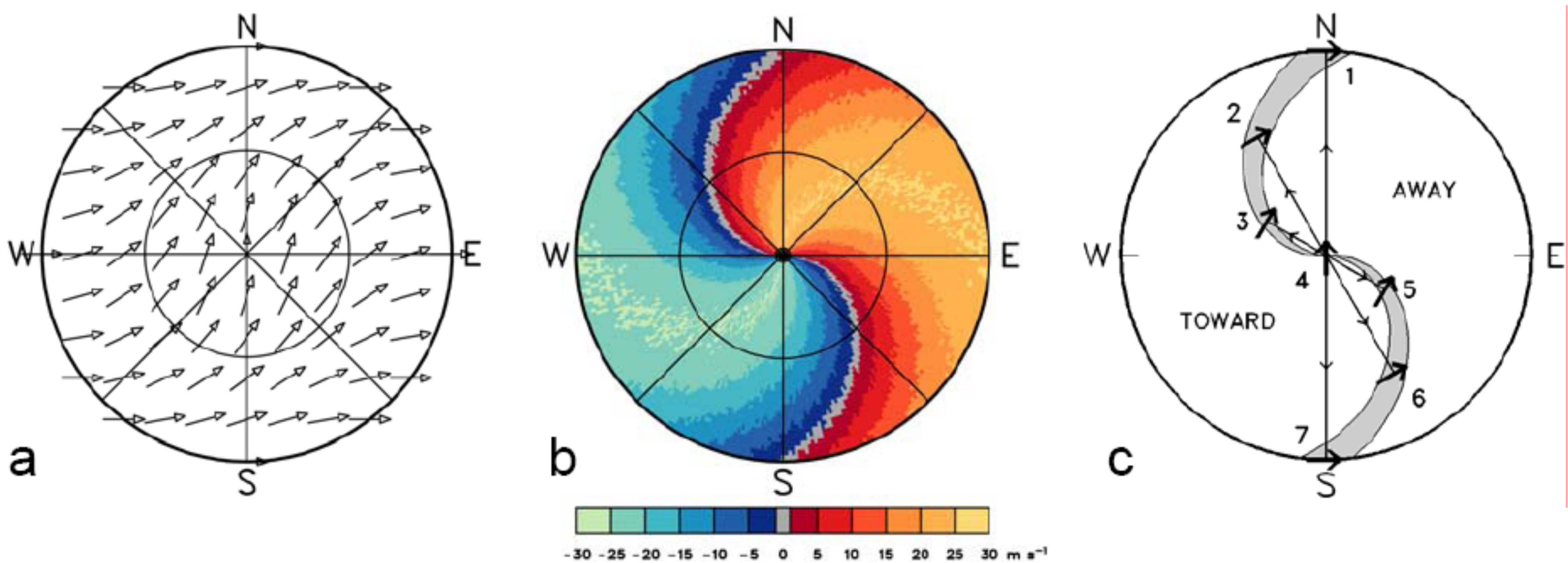


Fig. 2.1.2. Plan view of (a) environmental wind field and (b) corresponding single Doppler velocity pattern for wind with constant speed (26 m s^{-1} or 50 kt) and with direction changing uniformly from southerly at the ground (center of display) through southwesterly to westerly at the edge of the display. Part (c) illustrates how wind direction in a horizontally homogenous flow field can be interpreted using the zero Doppler velocity band. Uniform arrow length in (d)

Patterns associated with vertical profiles having constant wind directions

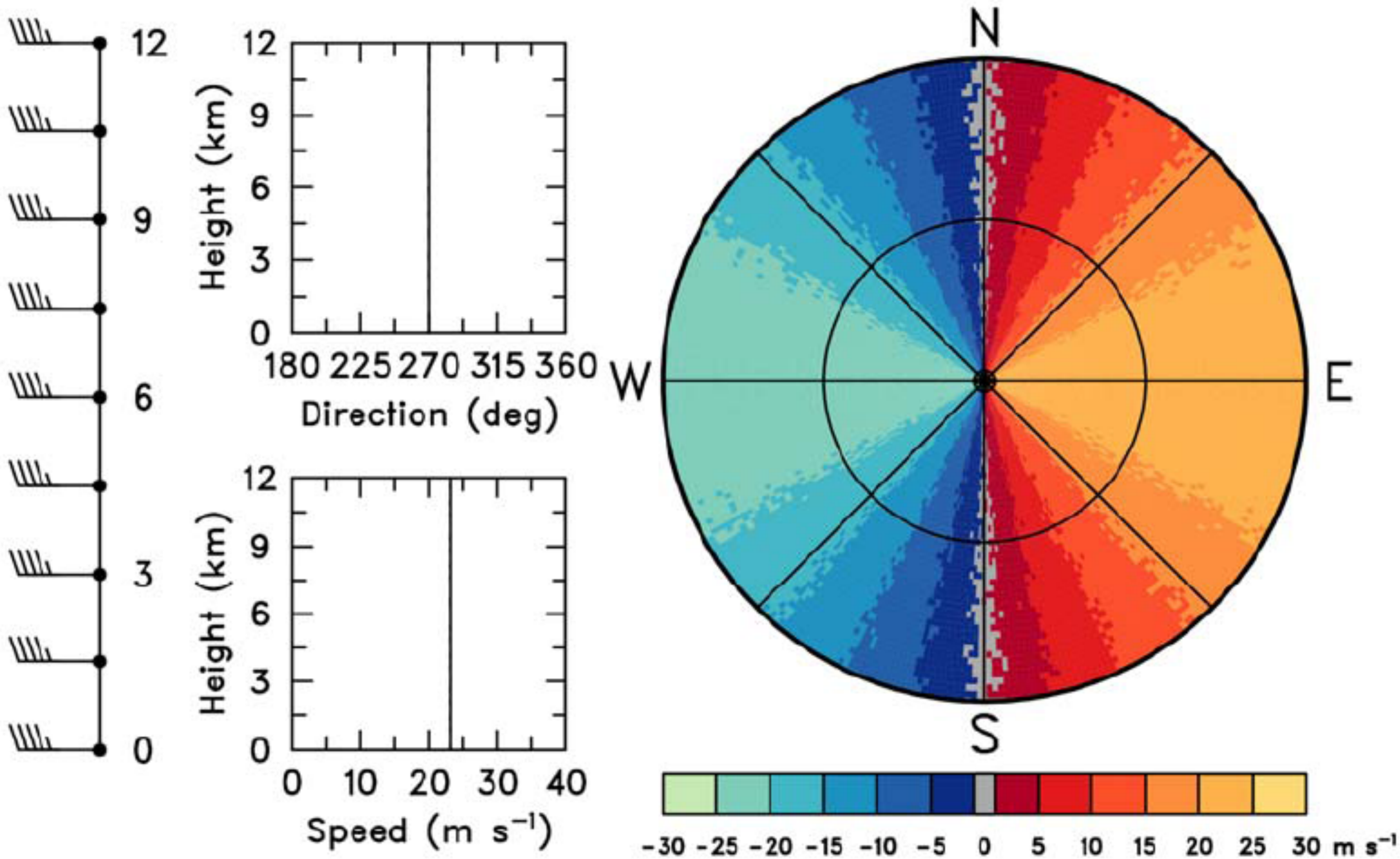


***Fig. 2.2.1**. Doppler velocity pattern (right) corresponding to a vertical wind profile (left) where both speed (23 m s^{-1} or 45 kt) and direction (270°) are constant with height. Negative (positive) Doppler velocities represent flow toward (away from) radar. Radar is at the center of the display.*

Patterns associated with vertical profiles having constant wind directions

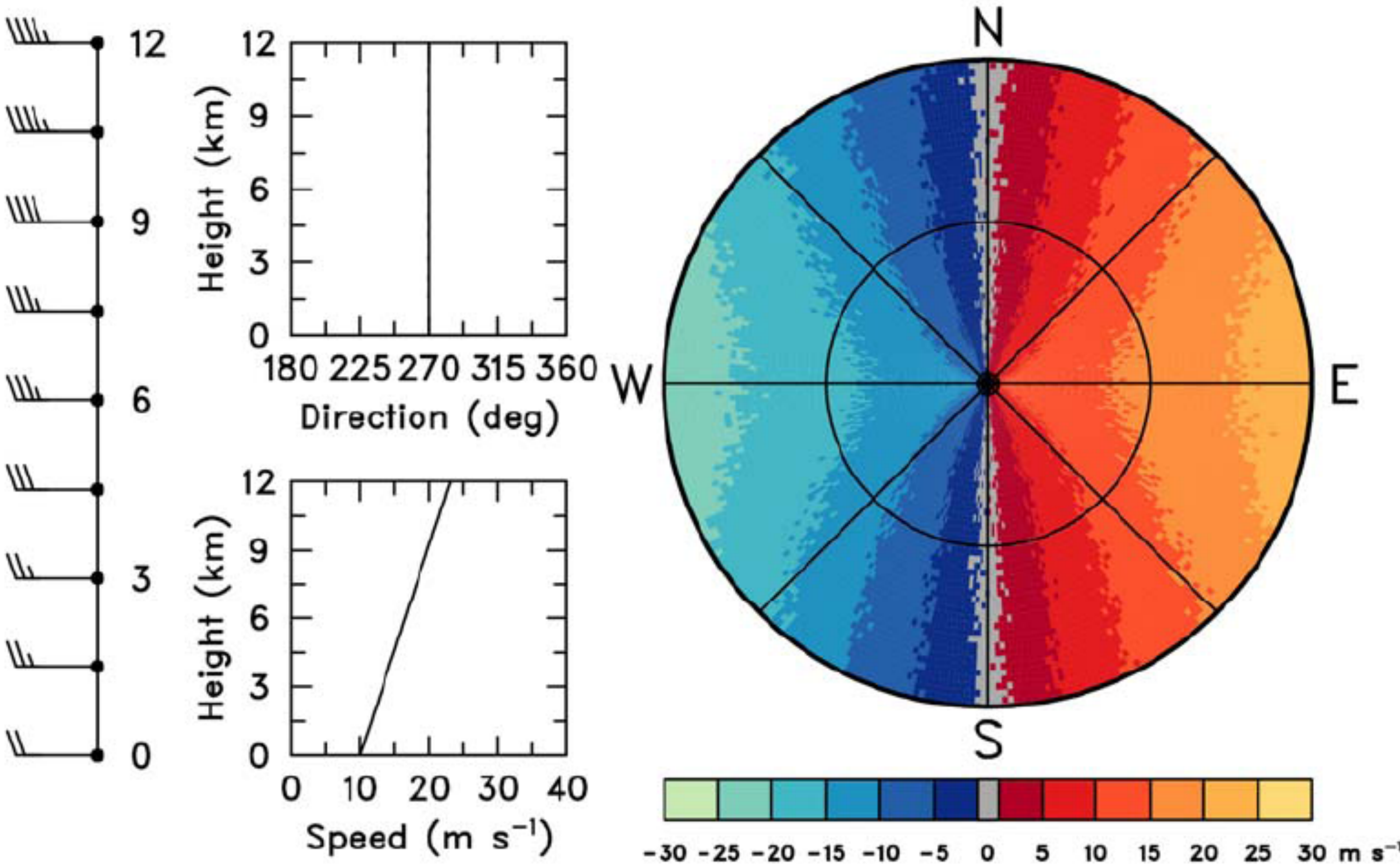


Fig. 2.2.2. *Same as Fig. 2.2.1, except that the wind speed increases from 10 m s^{-1} (19 kt) at the ground to 23 m s^{-1} (45 kt) at the edge of the display.*

Patterns associated with vertical profiles having constant wind directions

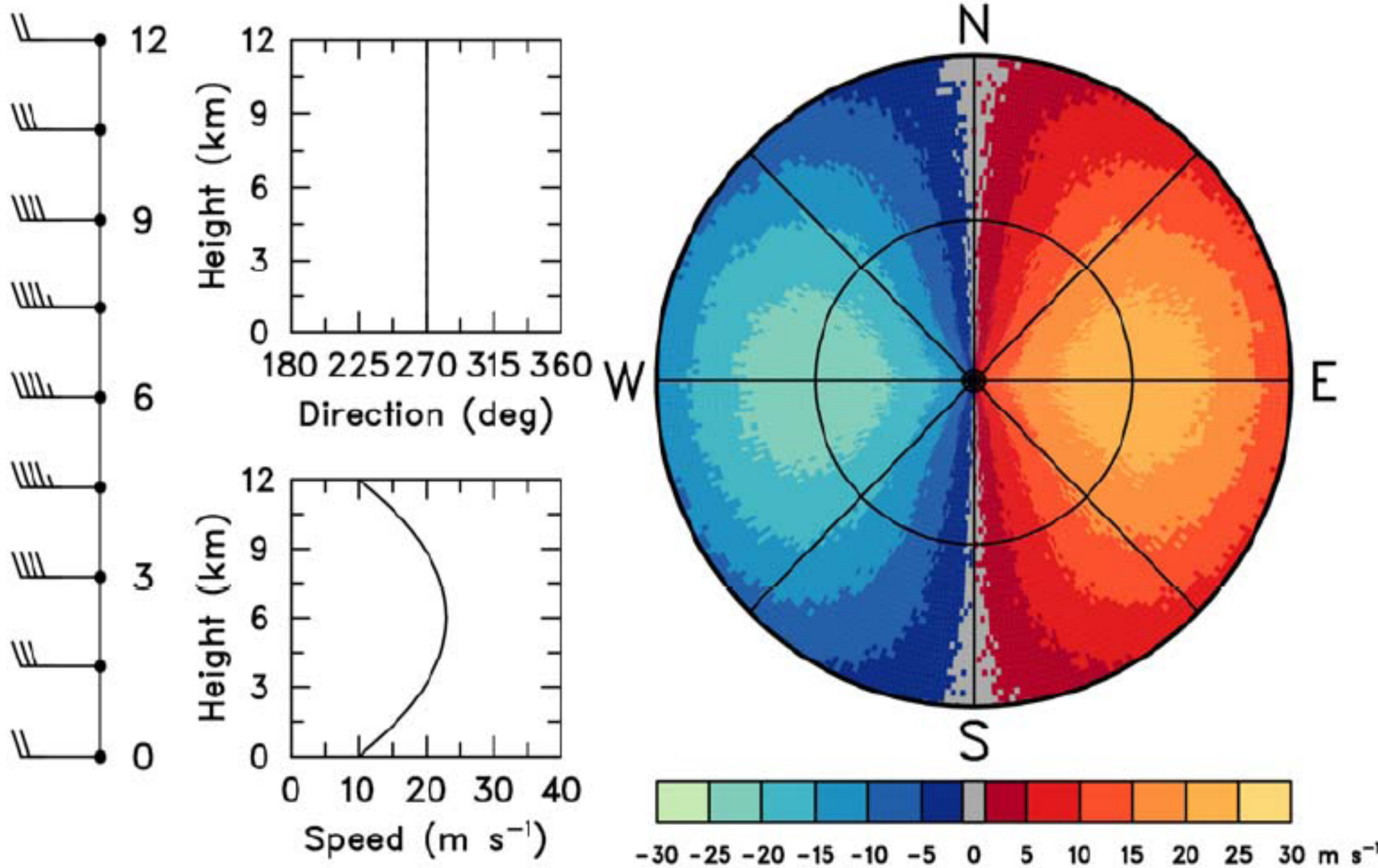


Fig. 2.2.3. Same as Fig. 2.2.1, except that the wind speed is a maximum of 23 m s^{-1} (45 kt) midway between the ground and the height corresponding to the edge of the display. Speed is 10 m s^{-1} (19 kt) at the surface and at the edge of the display.

Patterns associated with nonuniform horizontal wind fields (difluent)

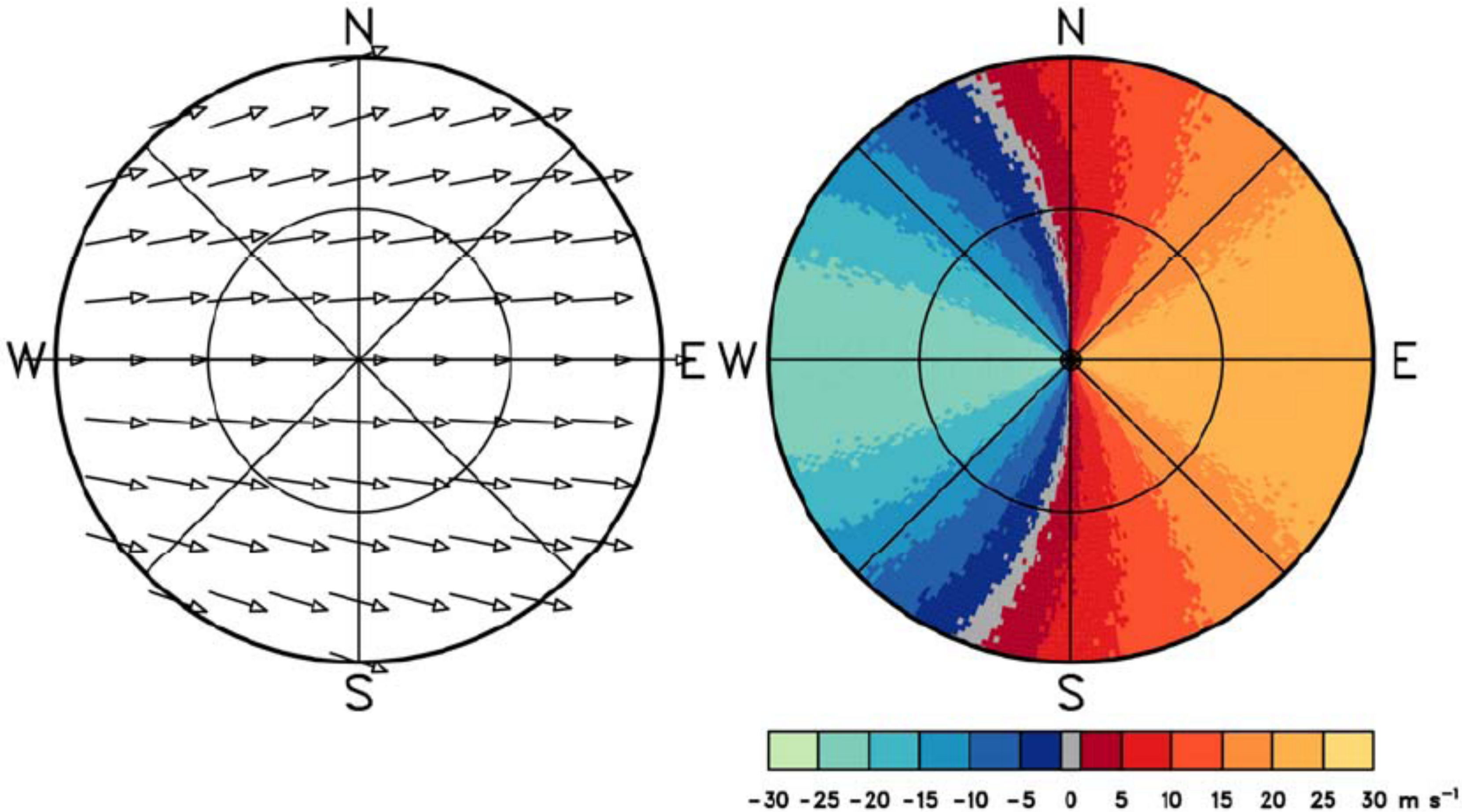


***Fig. 2.3.1**. Doppler velocity pattern (right) corresponding to a horizontal flow field that is difluent with the same speed (23 m s^{-1} or 45 kt) at all heights (left). Negative (positive) Doppler velocities represent flow toward (away from) the radar. Radar location is at the center of the display.*

Patterns associated with nonuniform horizontal wind fields (confluent)

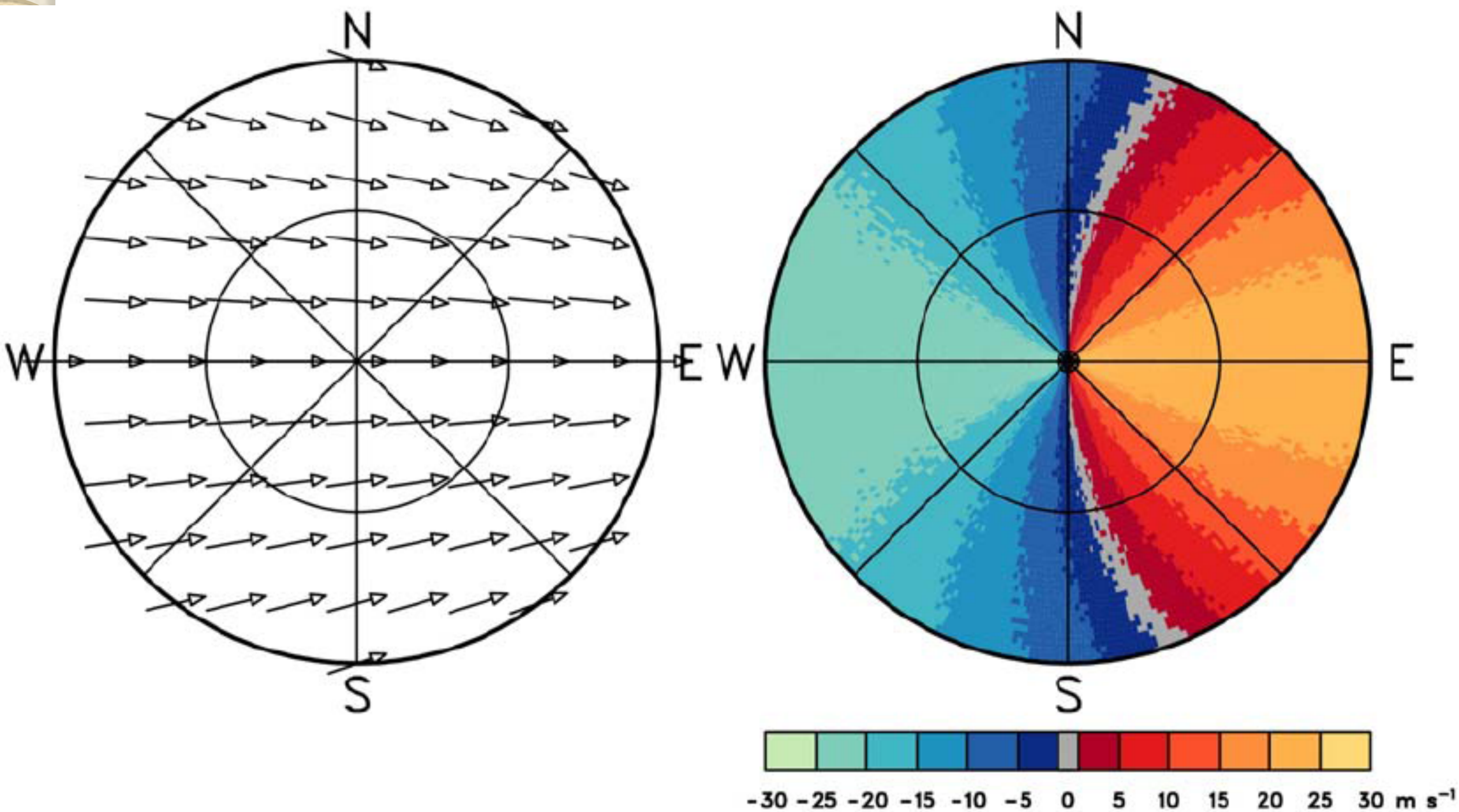


Fig. 2.3.2. *Same as Fig. 2.3.1, except that the horizontal flow field is confluent with the same speed (23 m s^{-1} or 45 kt) at all heights.*

Patterns associated with vertical profiles having constant wind speed

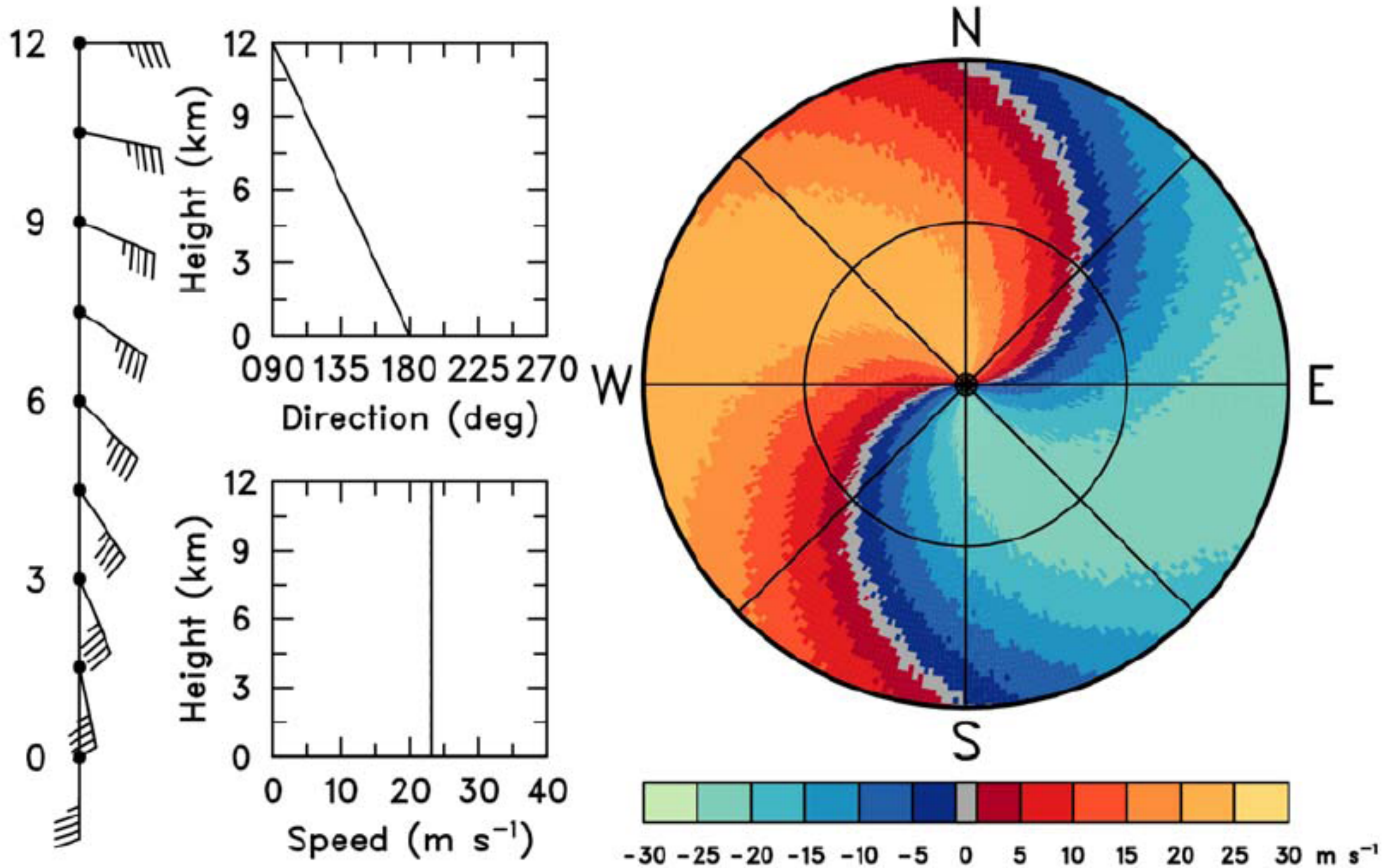
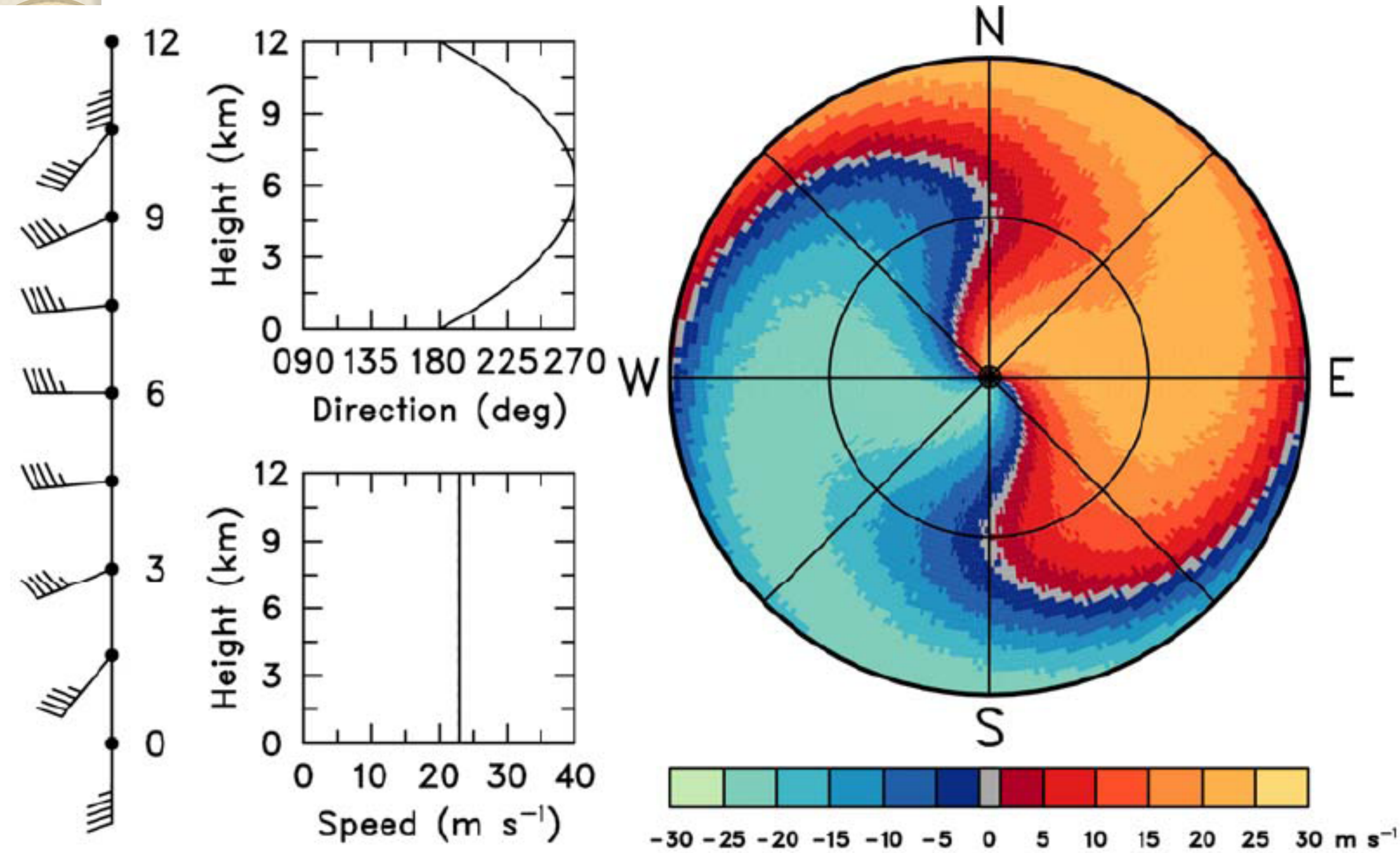
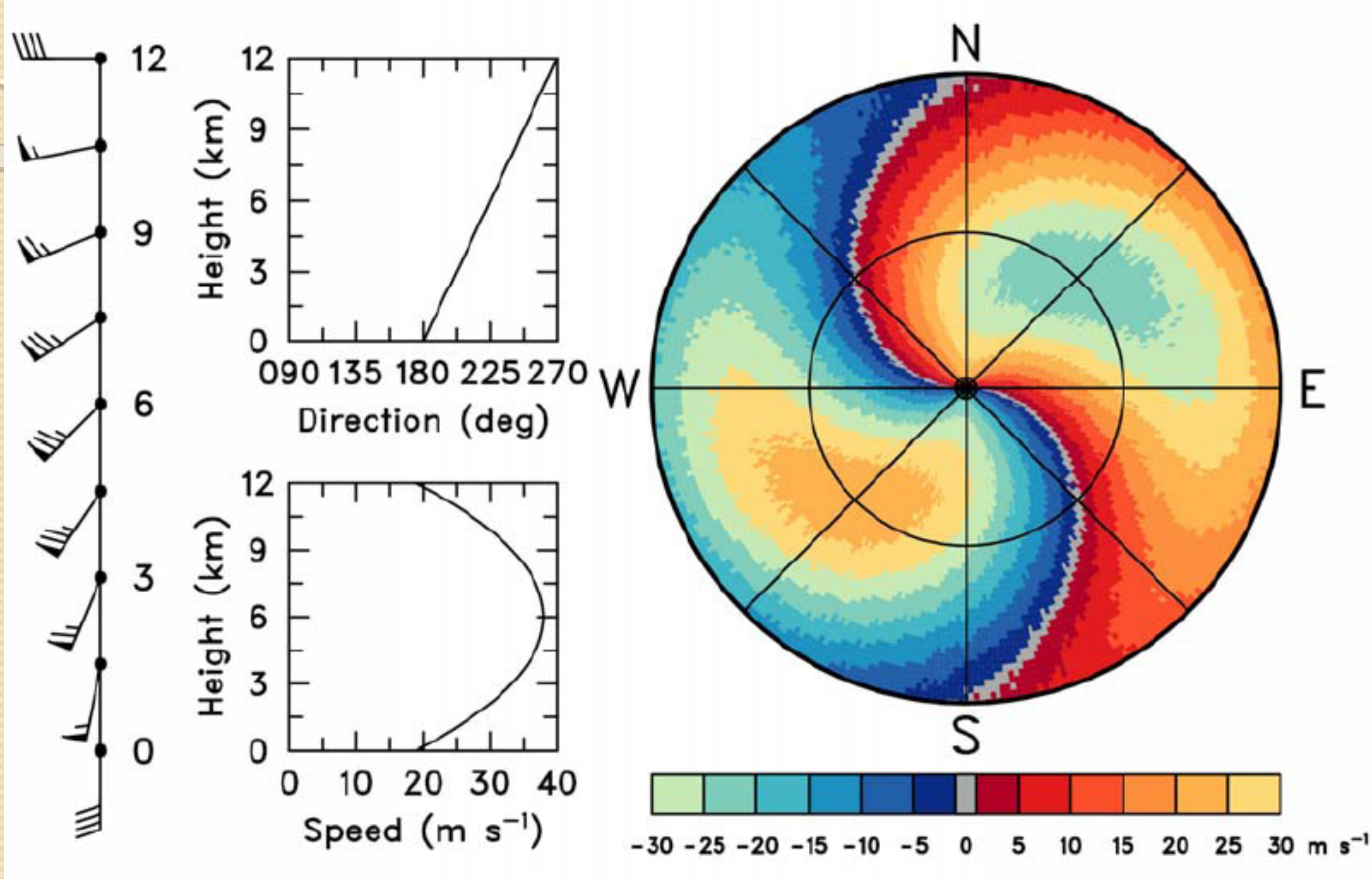


Fig. 2.4.1. *Doppler velocity pattern (right) corresponding to a vertical wind profile (left) with constant wind speed (23 m s^{-1} or 45 kt) and wind direction backing from southerly to easterly with height. Negative (positive) Doppler velocities represent flow toward (away from) the radar. Radar location is at the center of the display.*

Patterns associated with vertical profiles having constant wind speed



Patterns associated with vertical profiles of varying wind speed and direction



Patterns associated with horizontal discontinuities in the wind field

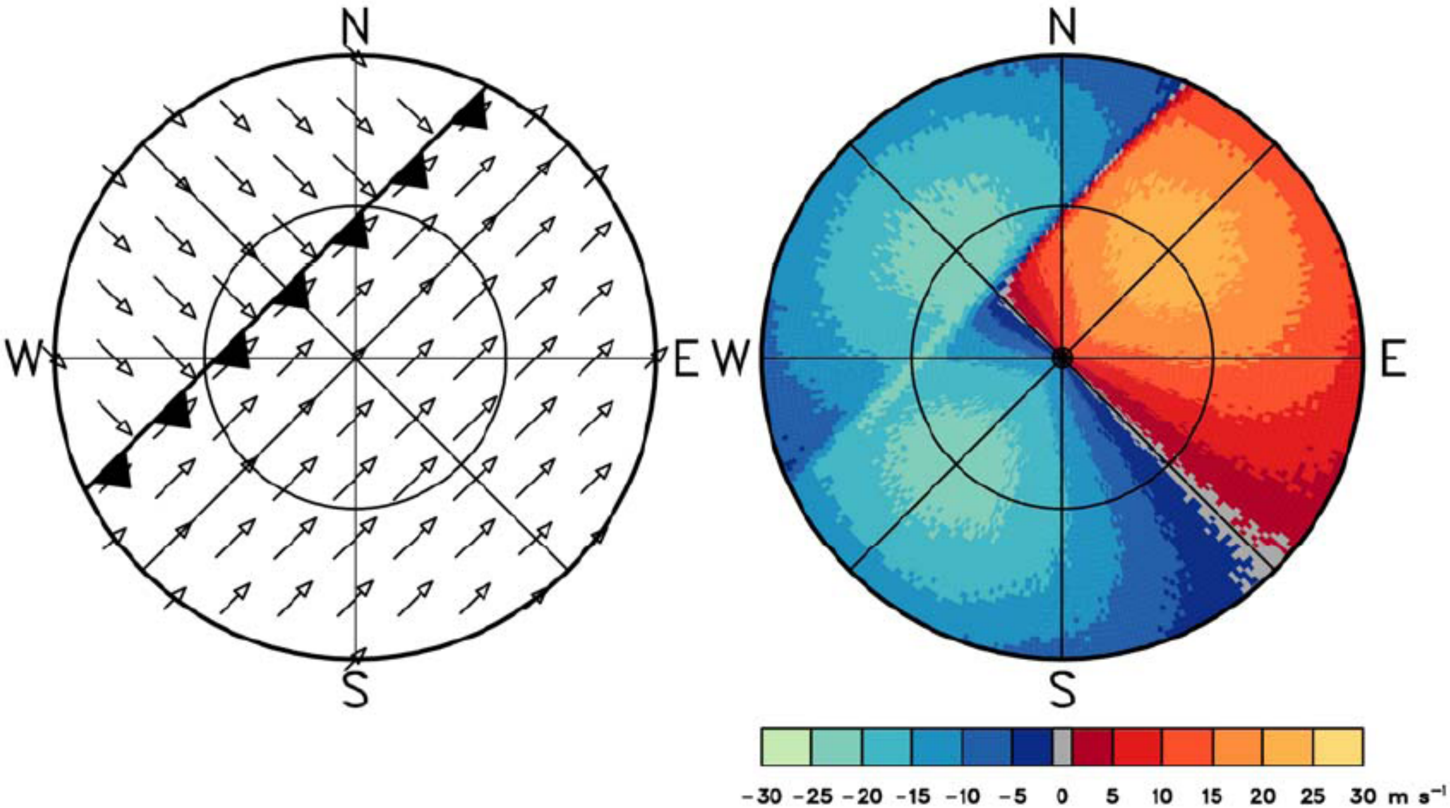
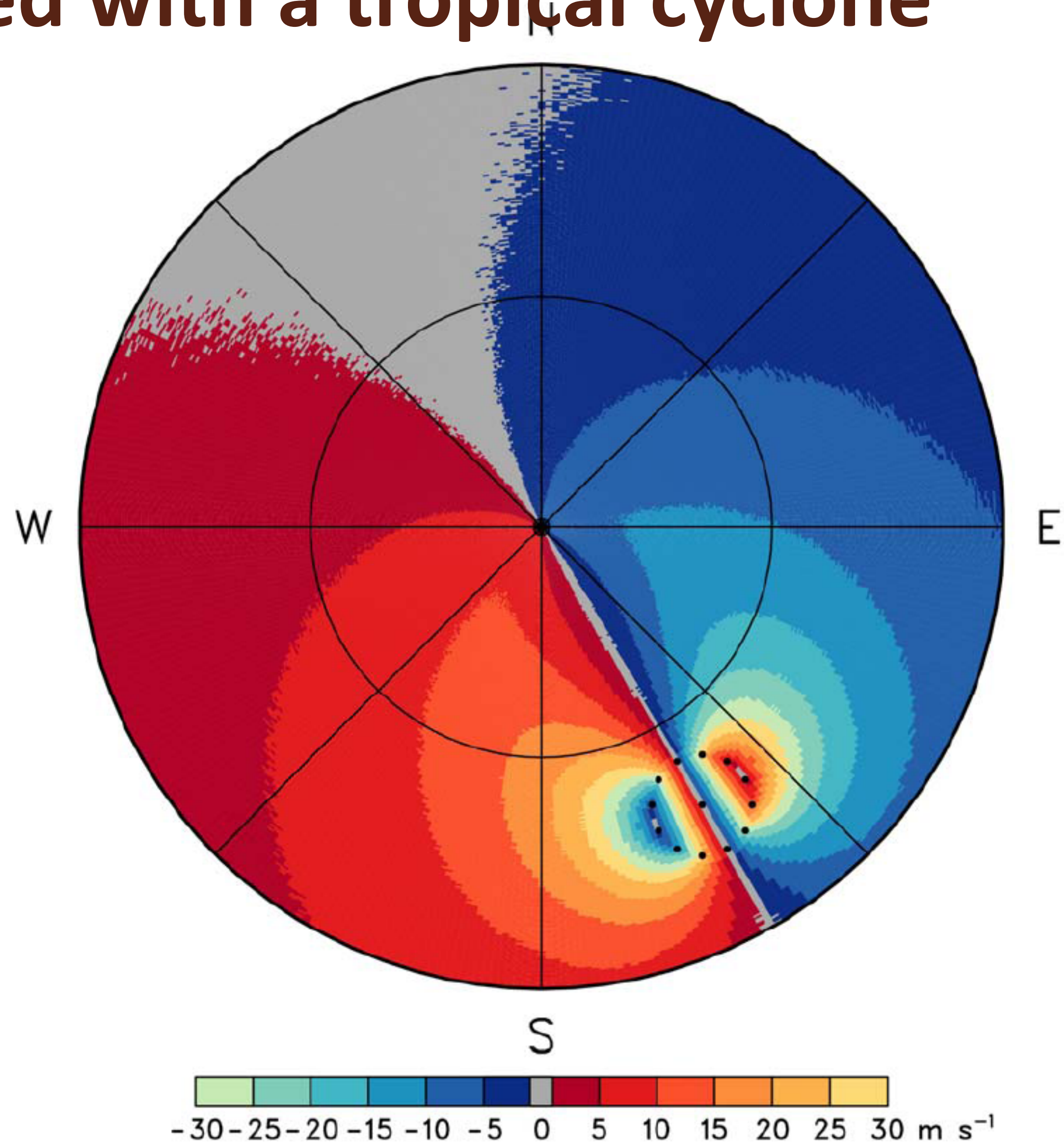


Fig. 2.7.1. *Doppler velocity pattern (right) corresponding to the approach of a wind field discontinuity from the northwest (left). There is a southwesterly low-altitude velocity maximum of 22 m s^{-1} (43 kt) ahead of the discontinuity and a northwesterly velocity maximum of 22 m s^{-1} (43 kt) behind it. Wind speed at the ground is 11 m s^{-1} (21 kt). Arrow length is proportional to wind speed. Negative (positive) Doppler velocities represent flow toward (away from) the radar. Radar location is at the center of the display.*

Patterns associated with a tropical cyclone

- Velocity folding occurred in this image.
- Doppler Vmax=30m/s
- After unfolding, the maximum real wind speed=60m/s



Patterns associated with a mesocyclone

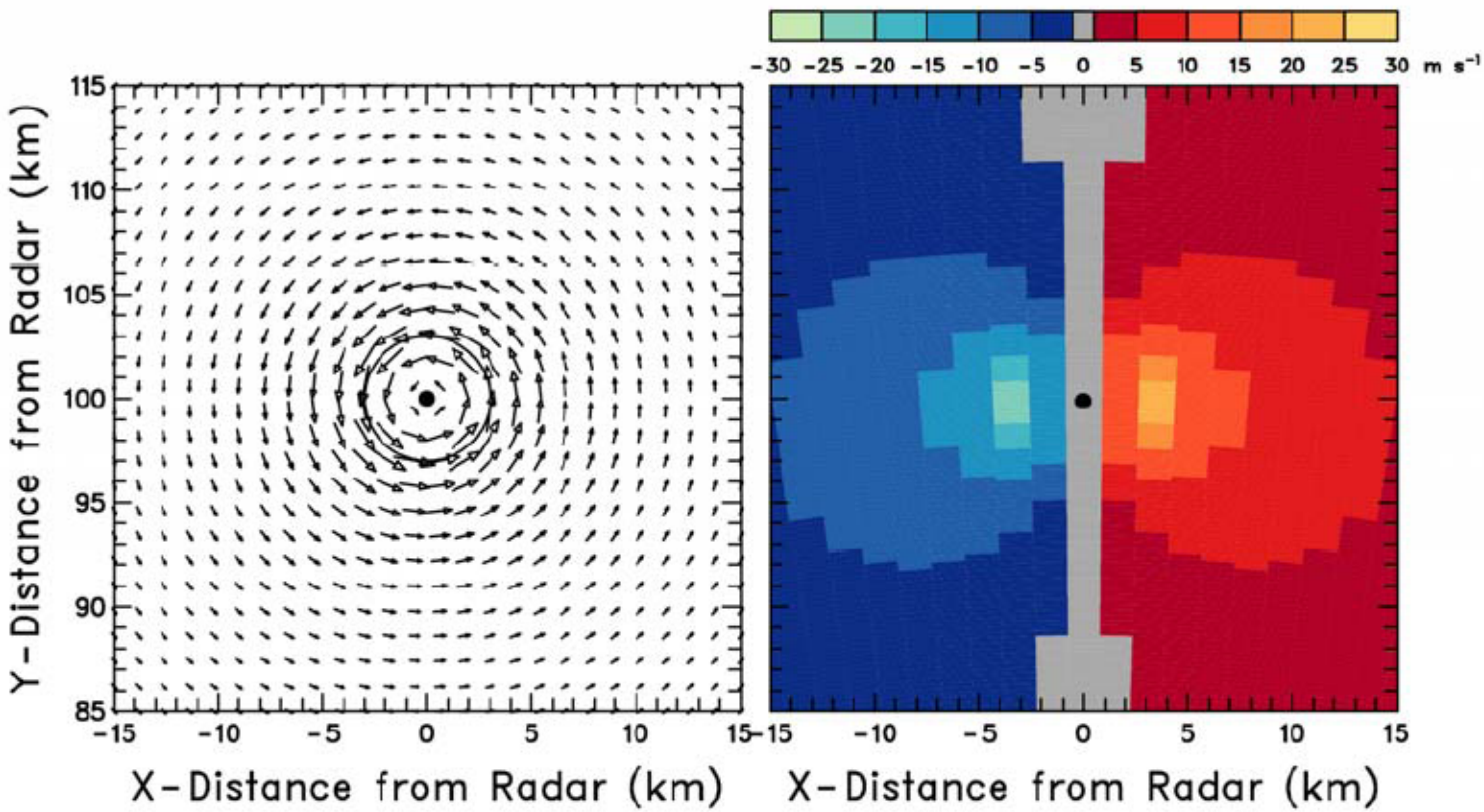


***Fig. 4.3.2**. Same as Fig. 4.3.1, except that the Doppler velocity pattern (right) corresponds to a mesocyclonic (left) that has peak tangential velocities of 25 m s^{-1} (49 kt) at a radius of 3 km (1.6 n mi) from the circulation center (black dot).*