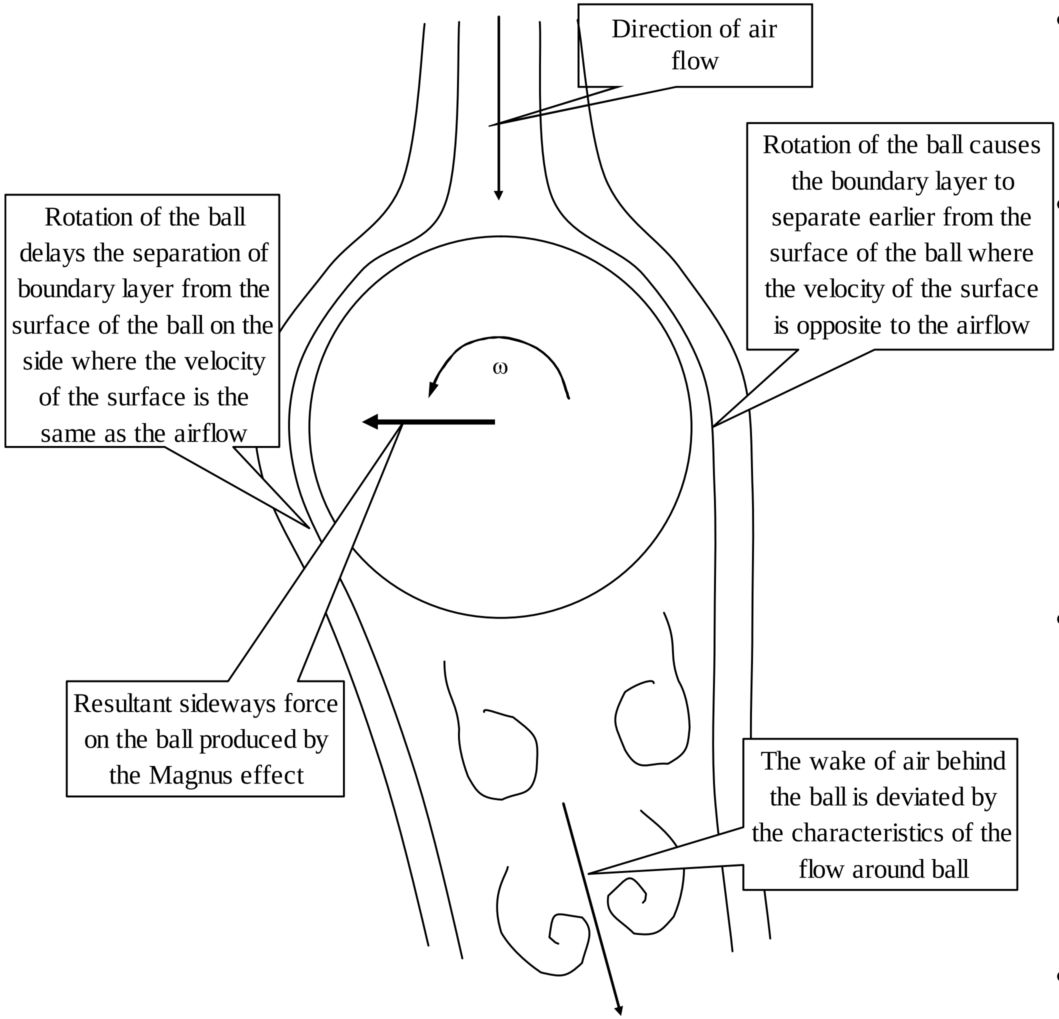
Spinning ball – swerve and drift

- Magnus effect – how spin affects the flight of the ball
- The swerve due to spin on a ball is well known in many sports
- In cricket it is mainly spinners that take advantage of the Magnus effect
- Magnus effect swerve on an old ball increases with the speed of the effective air flow over the ball and the amount of spin imparted
- The bowling trajectory model's predictions are similar to the experimental results for air flow velocities of more than 80kph
- There are two ways a spinner can create sideways movement of the ball in flight
- A spinner can use a combined swerve and drift to maximise sideways movement and still land on the seam to get maximum spin off the wicket
- Combined swerve and drift helps delay sideways movement till just before the ball bounces
- The direction of wind can have a substantial affect on the drift and swerve of the ball at even moderate wind strengths (i.e. 15 knots)

Magnus effect – how spin affects the flight of the ball



- The flow of air around a ball is affected by the ball spinning around an axis perpendicular to the direction of the flow
- The spin on the ball acts to cause the flow in the boundary layer on the side of the ball where the direction of the spin is against the airflow to separate earlier, while on the side where the spin is in the direction of the airflow the boundary layer will separate later
- This unsymmetrical air flow causes a sideways force to be exerted on the ball and the wake to be deviated to the opposite side (obeying Newton's 3rd law – the equal and opposite force), this is known as the Magnus effect
- Note the force acts perpendicular to both the direction of the flow and the spin axis

The swerve due to spin on a ball is well known in many sports

- The Magnus effect is apparent in many ball sports
  - Baseball pitchers use spin on the ball to make it curve as it travels to the striker
  - Table tennis balls are spun viciously to alter flight characteristics in many ways
  - Soccer players use spin as they kick the ball to ‘bend it like Beckham’
  - Tennis players use top-spin to help land harder hit balls in their opponent’s court
  - etc.

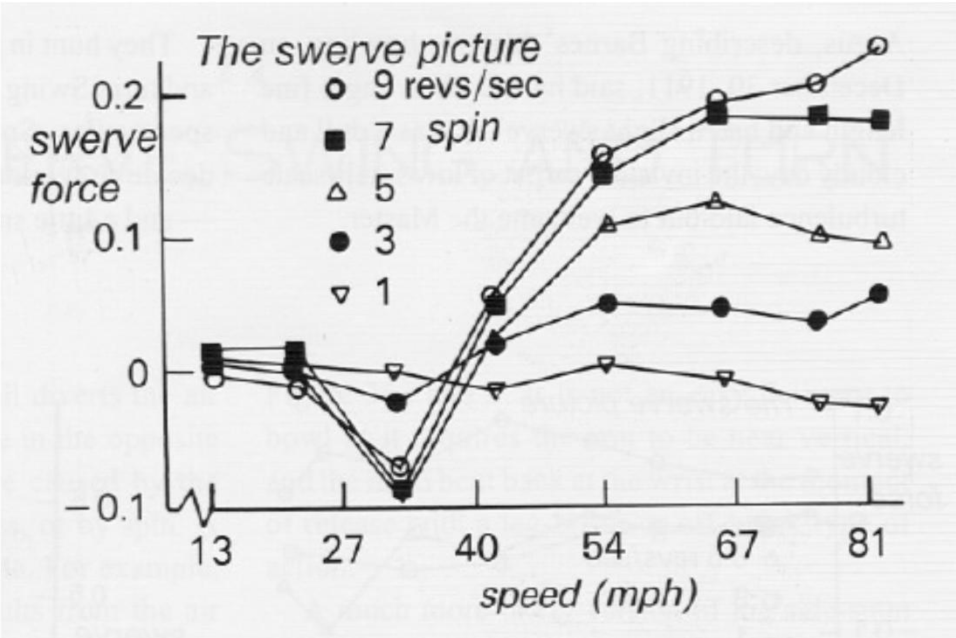
In cricket it is mainly spinners that take advantage of the Magnus effect

- Currently, it is the slower bowlers in cricket that typically use the Magnus effect on their deliveries
  - Apparently this was not always the case, with faster bowlers in the late 19th to mid 20th centuries often employing the Magnus effect to great advantage[1].
  - Most spinners use some top-spin in their deliveries to help increase the downwards acceleration on the ball, resulting in the ball pitching shorter than the batsman expects.
  - Sometimes, mainly by off-spinners bowling the ‘arm-ball’, the ball is spun so that it travels with spin around an axis that is pointing vertically, this will create lateral swerve as the ball travels down the wicket.
  - The drift by a spinner can be caused by a component of the spin acting around a vertical axis as for arm ball, and/or by the ‘side spin’ (the component around a horizontal axis) as the ball starts travelling vertically downwards towards the end of its flight down the wicket, we will call the former swerve (á la Wilkins) and the latter drift.
  - Some bowlers use back spin to create a faster, flatter trajectory ball that pitches further up the wicket than the batsman expects – e.g. the ‘flipper’
- Note that any spin on the ball may also cause it to behave differently as it bounces.

[1] Wilkins, Brian, (1997), ‘Cricket: the bowler’s art’, 2nd ed, Kangaroo Press

Magnus effect swerve on an old ball increases with the speed of the effective air flow over the ball and the amount of spin imparted

Swerve on a worn (100 overs) 4-piece ball[1]

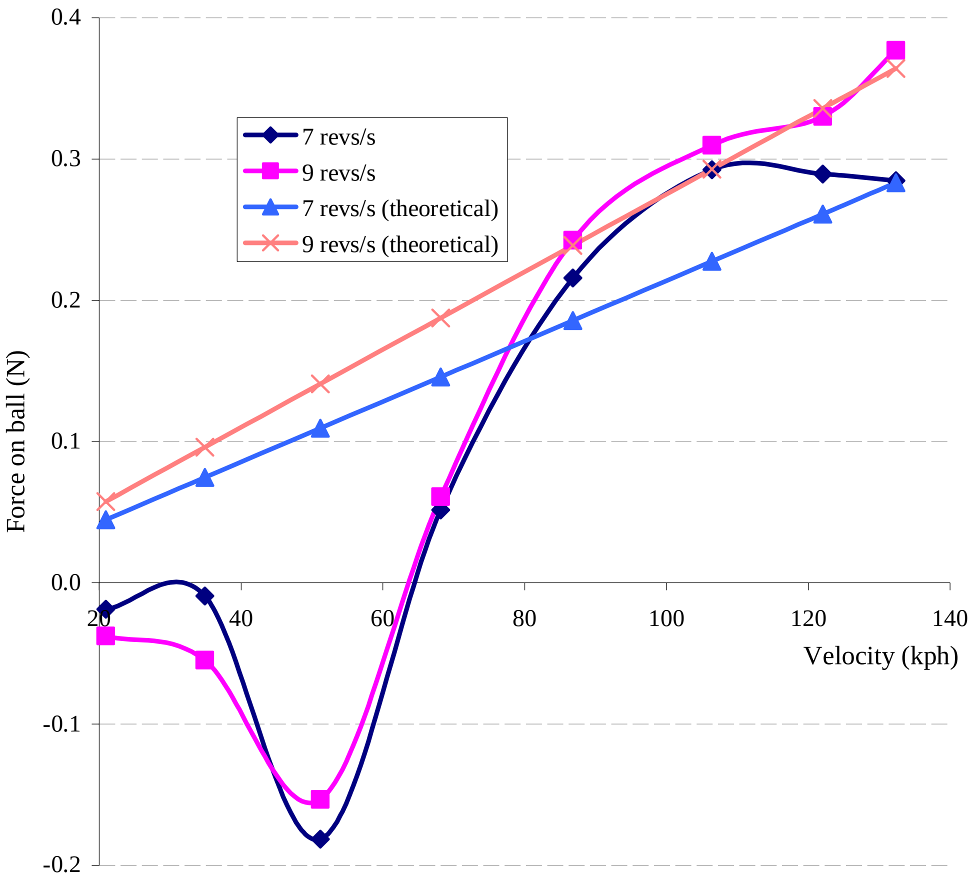


- There is not much experimental data relating to the Magnus effect on a cricket ball except for that done by Brian Wilkins[1]
  - Unfortunately his data is not reported in terms of Reynolds number and so it is difficult to use in any model that wants to account for differences in atmospheric conditions
  - Swerve force is reported as a ratio of the weight of the ball
- The ball needs to be travelling at an effective air flow speed of more than 60kph before Magnus effect starts to happen and it tends to increase with the speed of the ball
- The greater the spin rate, the higher the forces on the ball and hence the greater the amount of swerve
- Apparently spinners are able to get up to about 15 rev/s of spin on the ball

[1] Wilkins, Brian, (1997), 'Cricket: the bowler's art', 2nd ed, Kangaroo Press

The bowling trajectory model's predictions are similar to the experimental results for air flow velocities of more than 80kph

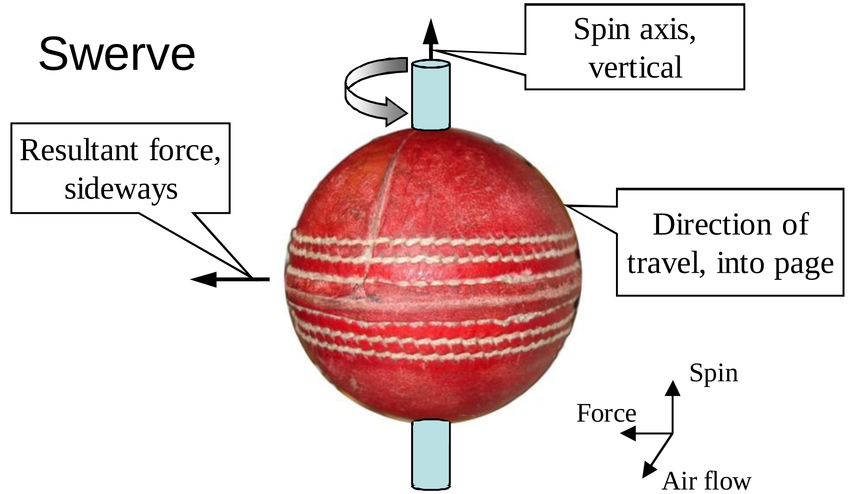
Comparison between theoretical and experimental Magnus effect forces on ball

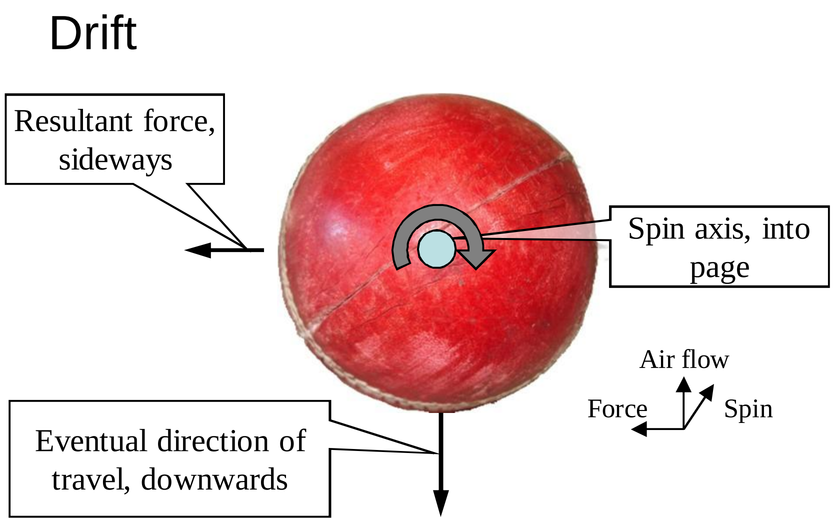


Source: Vaughan Roberts' bowling trajectory model

- The results of model's predictions about the force on the ball due to the Magnus effect are a reasonable fit with the experimental results for the worn ball at air flow velocities of 80kph or greater
- For points at greater than 80kph, the Student-t test gives the fit between the model and the experimental data as:
  - correlation significant at p = 0.8 for 7 revs/s
  - correlation significant at p = 0.98 for 9 revs/s
- As most spinners bowl at 80kph or higher, and mainly into the wind which increases the effective air flow past the ball, the model is accurate in the region where predictions are likely to be made
- The peculiar lower speed results can not be explained by me and may be an artefact of the conditions of the experiment
- *Assumptions*: Wilkins carried out, or normalised, his results to standard atmospheric conditions; the wear on the ball does not impact on the generation of the force due to the Magnus effect

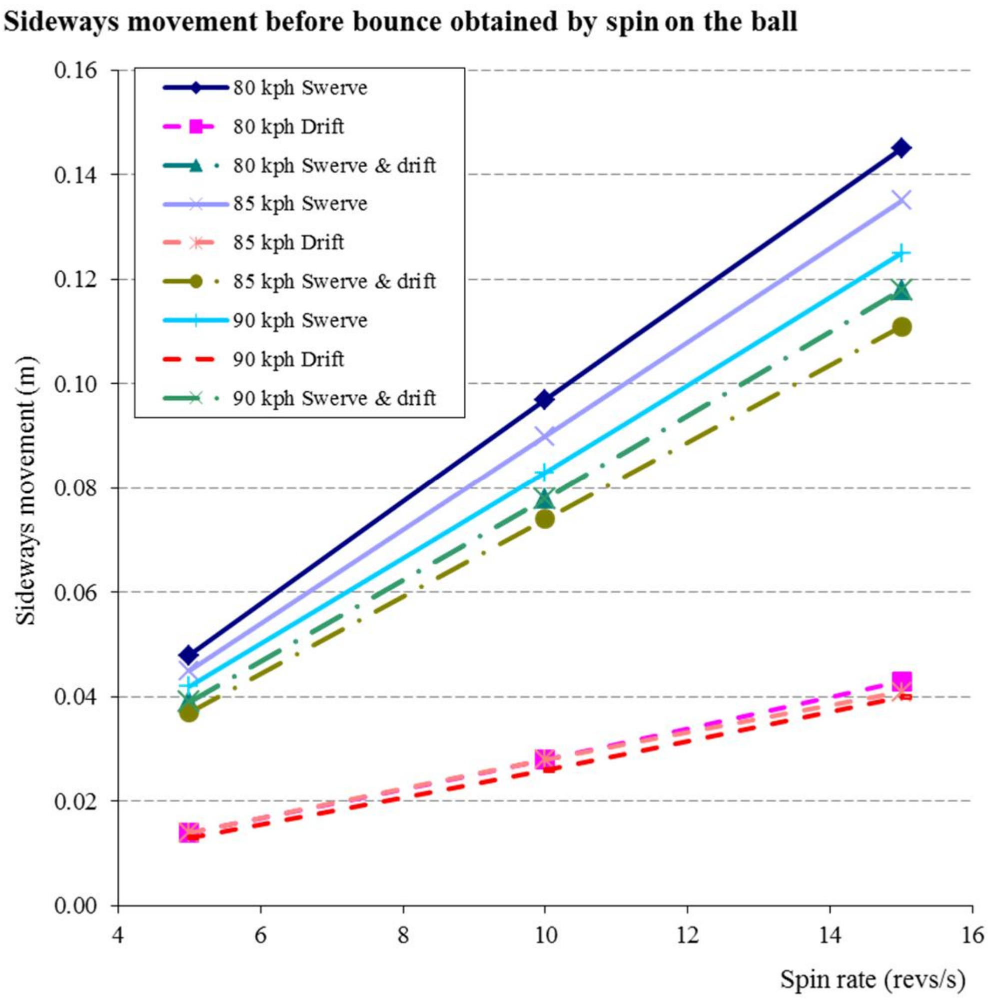
There are two ways a spinner can create sideways movement of the ball in flight





- The Magnus effect produces forces on the ball that are mutually perpendicular to the air flow over the ball and the spin axis
  - When the spin axis and the air flow are in the same direction there is no force on the ball
- A spinner can utilise this effect to create sideways movement in two ways:
  - Swerve – use the horizontal velocity of the ball travelling toward the batsman and a vertical spin axis (see top diagram), or
  - Drift – use the vertical velocity of the ball as it nears the batsman and a horizontal spin axis (see bottom diagram)
- In practice the sideways movement is always likely to be a combination of these two effects because the trajectory of a ball delivered at 80kph will go from almost horizontal as it leaves the bowlers hand to about 20^{o} to the horizontal just before bouncing (no topspin).
- So for a ball spun about a horizontal axis, it will have a drift component and a swerve component (both of which are proportional to the sine of the angle from horizontal)

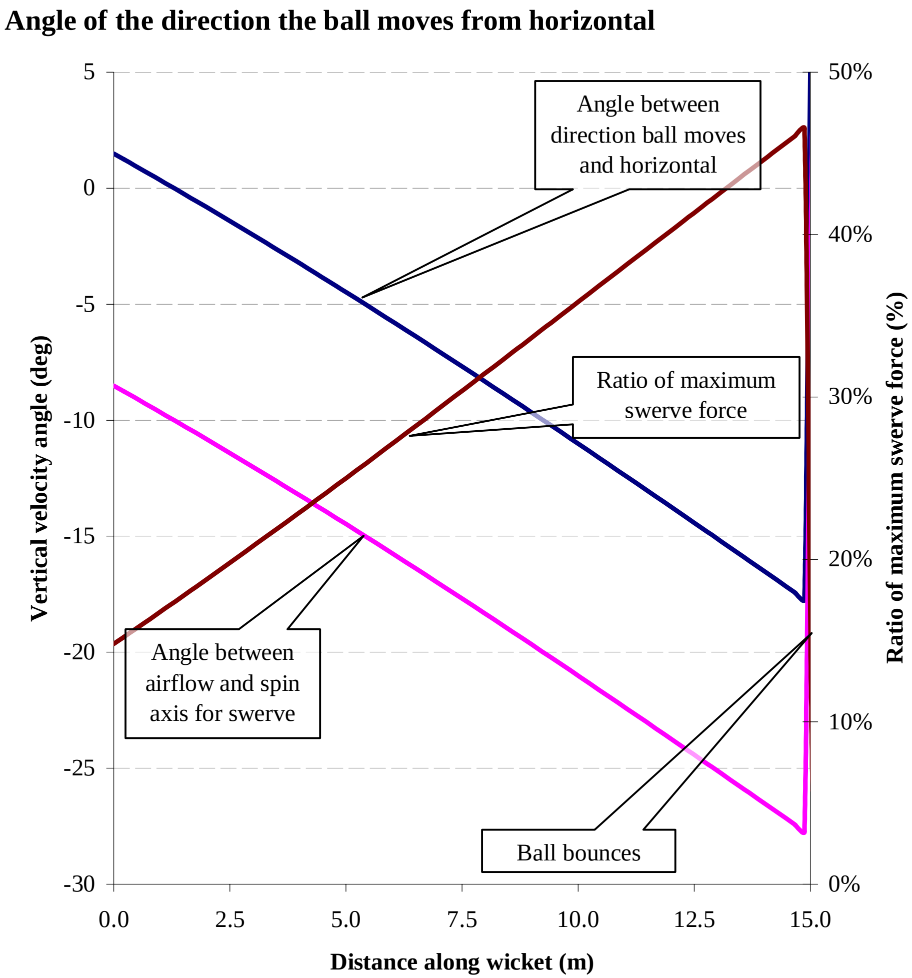
A spinner can use a combined swerve and drift to maximise sideways movement and still land on the seam to get maximum spin off the wicket



Source: Vaughan Roberts' bowling trajectory model

- Pure swerve (the spin axis points vertically) produces the greatest sideways movement due to a combination of the amount of spin and the mainly horizontal air flow (solid lines)
  - The slower the delivery, the greater the sideways movement due to the longer flight time
- Pure drift (the spin axis points horizontally towards the batsman) produces only small amounts of sideways movement due to little exposure to a vertical air flow
  - The slower the delivery, the greater the drift due to the slightly higher trajectory required to get the ball to bounce on a good length
  - The drift occurs late in the flight as it is dependent on the ball picking up downward speed
- A combined swerve and drift (spin axis with 10^{o} elevation) produces almost the same sideways movement as pure swerve and at this angle it will still land on the seam and take almost maximum spin off the wicket
  - The slower the delivery, the greater the sideways movement mainly due to the longer flight time
- *Assumptions*: standard atmospheric conditions, no wind, a bounce distance of 2.5 metres from the batting crease and an 0.2s air flow time delay

Combined swerve and drift helps delay sideways movement till just before the ball bounces

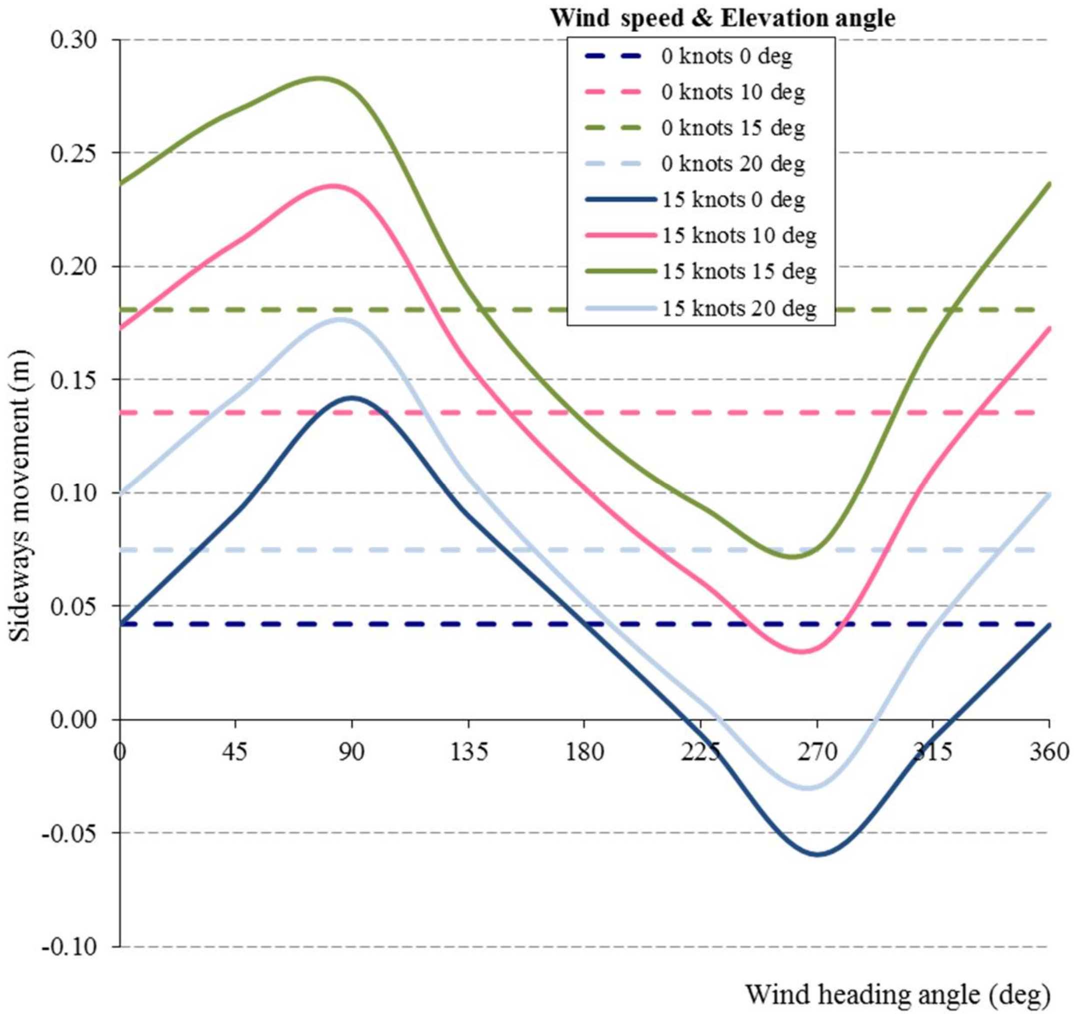


Source: Vaughan Roberts' bowling trajectory model

- With a combined swerve and drift by tilting the axis of spin from horizontal with a 10^o elevation to increase the amount of sideways movement, the onset of the movement is delayed by two effects:
  - Drift only occurs as the downwards velocity of the ball increases towards the bounce
  - The amount of swerve is dependent on the angle between the effective airflow and the spin axis of the ball which increases as the ball travels down the wicket
  - The swerve force as a ratio of maximum swerve force, increases from ~15% when the ball leaves the bowler's hand to almost 50% just as the ball bounces
- *Assumptions:* standard atmospheric conditions; ball delivered at 80kph with 10 revs/s spin; horizontal spin axis tilted with 10^o of elevation; no wind; ball to bounce 2.5 metres in front of batting crease, delivered from 2.1 metres above wicket

The direction of wind can have a substantial affect on the drift and swerve of the ball at even moderate wind strengths (i.e. 15 knots)

Swerve and drift at bounce for different wind direction and spin elevation angles



Source: Vaughan Roberts' bowling trajectory model

- At zero elevation angle (i.e. no swerve), the wind coming from the side that assists your drift will increase the sideways movement of the ball compared with no wind
  - Once the wind comes from the non-assisting side, the sideways movement falls away quickly, eventually achieving little, or negative, drift
- When using combined swerve and drift at the best elevation angles (between 10-15 degrees) you can get 50% more sideways movement by bowling into a 15 knot head or assisting side wind than on a still day
  - Once the wind becomes a trailing or non-assisting wind, the sideways movement falls to less than half that achieved otherwise
- *Assumptions:* standard atmospheric conditions; ball delivered at 85kph; 15 knot wind; spin of 15 revs/s; ball to bounce 2.5 metres in front of batting crease, delivered from 2.1 metres above wicket; no initial air flow delay