Drag forces on the ball

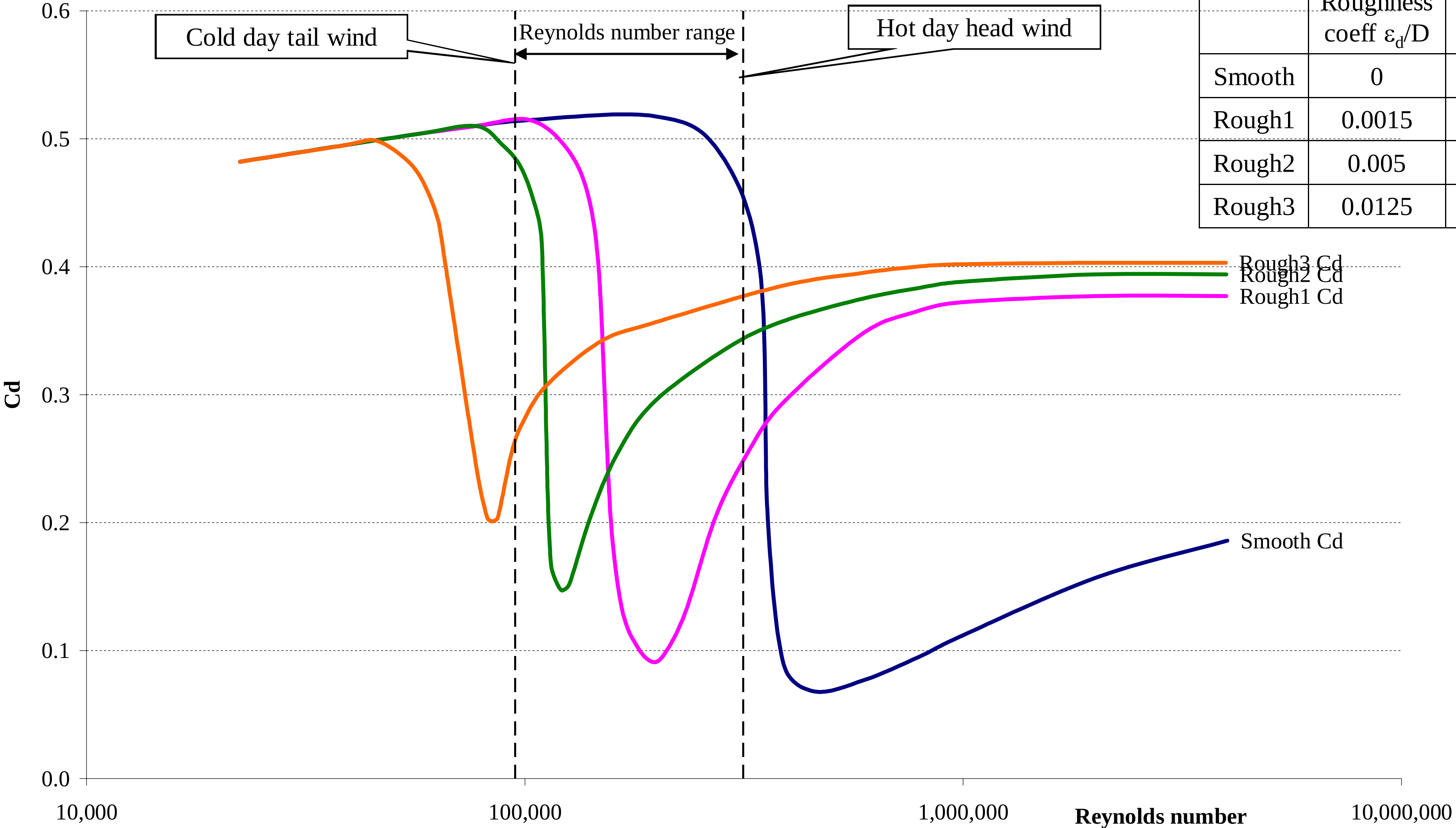
- Drag forces
- For a ball delivered at 140kph, the amount of drag can vary a lot depending on the roughness of its surface, wind and atmospheric conditions
- For a ball delivered at 140kph, an old ball behaves as one would expect…
- …, however for an almost new ball, the dramatic differences in Cd around the critical Reynolds number lead to some unintuitive results
- As the weather conditions change, the impact of wind drag on an almost new ball is quite complex, with some unexpected outcomes…
- In a side wind, the drag forces will cause an older ball to move further sideways than a newer ball

Drag forces

- Drag forces act to slow the ball down as it moves through the air
- They act in the direction opposite to the apparent wind, which is made up of the instantaneous direction and velocity of the ball and the direction and strength of the wind
- The amount of drag force on the ball is determined from the coefficient of drag, the density of the air and the velocity of the ball
- The coefficient of drag (C_d) is usually determined experimentally in a wind tunnel, see chart on following slide
  - C_d is plotted against a non-dimensional number, the Reynolds number, which normalises the experimental results for atmospheric conditions and a characteristic dimension of the object: in this case the diameter of the ball
  - Reynolds number is proportional to the velocity of the air over the ball
  - C_d is dependent on the roughness of the surface of the ball
  - the so-called ‘critical Reynolds number’ is that at which there is a substantial drop in the value of C_d

For a ball delivered at 140kph, the amount of drag can vary a lot depending on the roughness of its surface, wind and atmospheric conditions

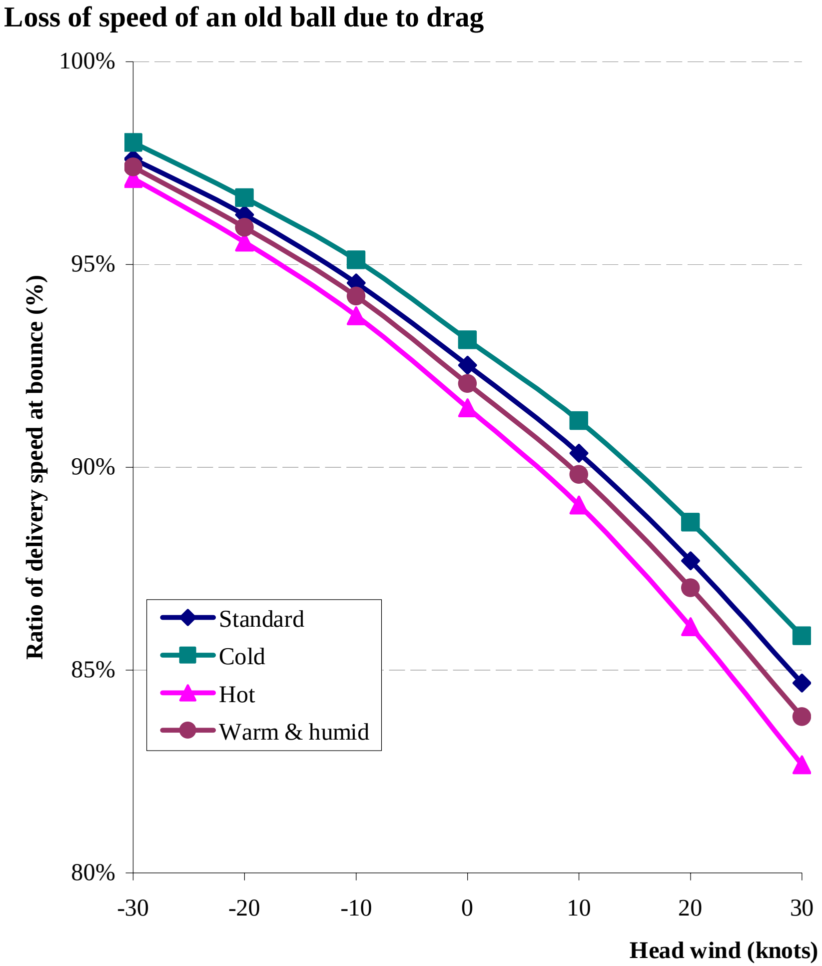
Drag coefficient of cricket balls with different surface roughness by Reynolds number



	Roughness coeff ε_d/D	Roughness (mm)
Smooth	0	0
Rough1	0.0015	0.11
Rough2	0.005	0.36
Rough3	0.0125	0.9

Source: Phil ??, (2003), chappellway.com.au/Images/Uploads/ball%20drag.doc

For a ball delivered at 140kph, an old ball behaves as one would expect…

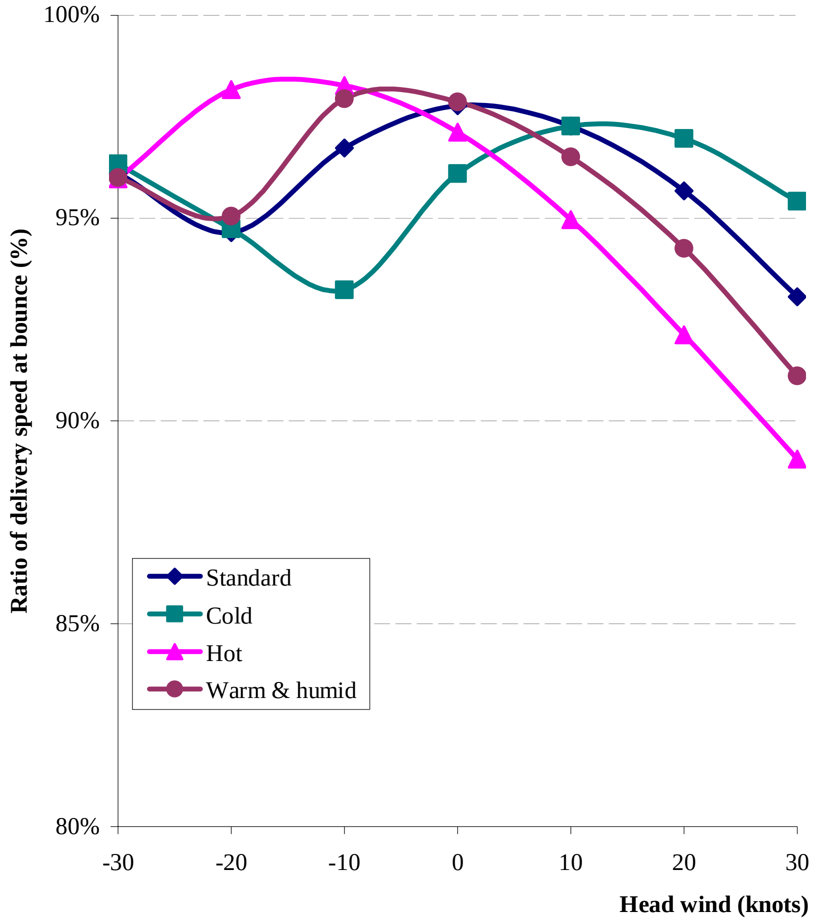


Source: Vaughan Roberts' bowling trajectory model

- Old ball with roughness of < 0.9mm
- There is less drag force on a cold day than on a hot day, due to the lower air pressure which results in lower density of the air
- The amount of drag increases as the strength of the head wind increases
- NB negative head wind is a tail wind
- *Assumptions*: ball delivered to bounce on the batting crease to eliminate loss of velocity due to bounce, use maximum surface roughness case from experimental drag data, linear interpolation used from experimental results

…, however for an almost new ball, the dramatic differences in C_d around the critical Reynolds number lead to some unintuitive results

Loss of speed of an almost new ball due to drag



Source: Vaughan Roberts' bowling trajectory model

- Almost new ball with roughness < 0.11mm
- In cold to cool weather there is less drag on an almost new ball when bowling into a moderate wind than when bowling with the wind due to the flow being pre-critical down-wind (C_d ~ 0.5) and post-critical into the wind (C_d ~ 0.1), therefore it is faster to bowl into the wind than with the wind
- In hot weather it is faster to bowl downwind, though a stronger wind helps less than a bowler would like
- NB negative head wind is a tail wind
- *Assumptions*: ball delivered to bounce on the batting crease to eliminate loss of velocity due to bounce, linear interpolation used from experimental results

As the weather conditions change, the impact of wind drag on an almost new ball is quite complex, with some unexpected outcomes…

The loss in velocity on a full toss delivered at 140kph with an almost new ball by the time it reaches the batting crease of a ball (surface roughness <0.11mm)

The wind affects the ball more on hot days as the air density and Cd is higher

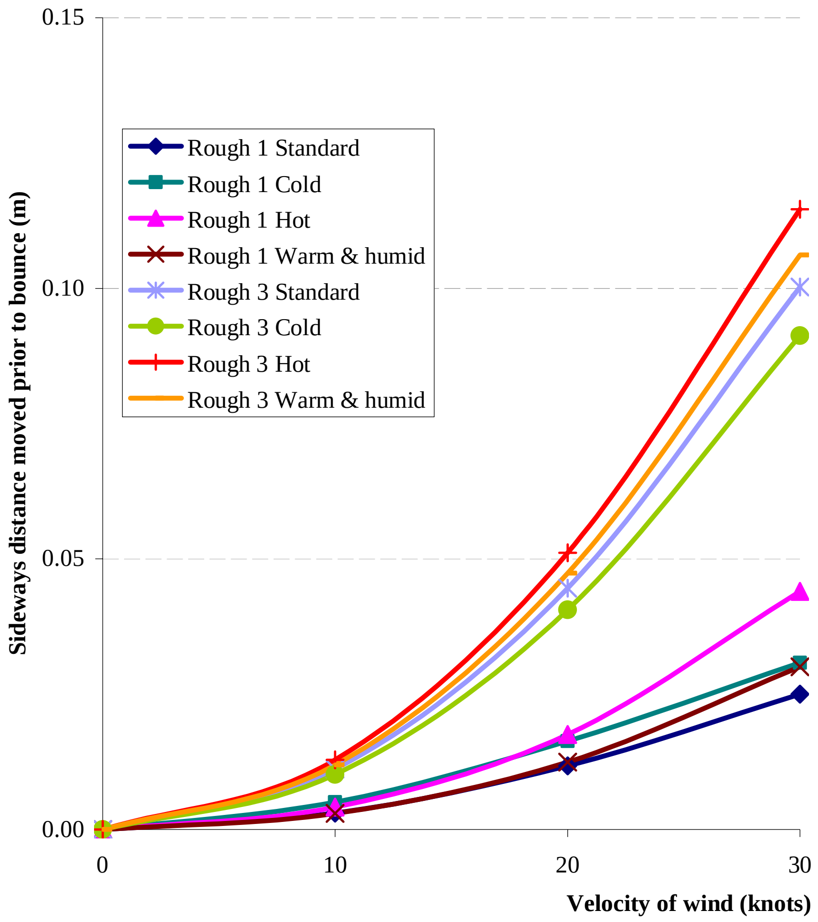
It is faster to bowl a new ball into the wind on a cold day, due to lower Cd

	Horizontal velocity lost by drag (%)								
	No wind			**20 knot head wind**			**20 knot tail wind**		
	Loss	Re (10^3)	Cd	**Loss**	Re (10^3)	Cd	**Loss**	Re (10^3)	Cd
Cold day	**5.10%**	160 - 154	.182 - .264	**3.63%**	202 - 198	.094 - .091	**6.42%**	118 - 111	.5 - .507
Standard atmosphere	**2.71%**	183 - 180	.101 - .105	**5.13%**	231 - 224	.129 - .119	**6.57%**	135 - 126	.468 - .488
Warm, humid day	**2.56%**	200 - 197	.093 - .091	**6.76%**	252 - 241	.166 - .146	**6.24%**	147 - 139	.401 - .456
Hot, dry day	**3.41%**	224 - 220	.119 - .113	**9.28%**	283 - 265	.215 - .191	**2.46%**	165 - 164	.145 - .152

Source: Vaughan Roberts' bowling trajectory model

In a side wind, the drag forces will cause an older ball to move further sideways than a newer ball

Impact of a side wind on a cricket ball delivered at 140kph



Source: Vaughan Roberts' bowling trajectory model

- A side wind has significantly more effect on sideways movement with an old ball than a newer one
- The impact of the wind can cause an old ball to move as much as four times further than a newer one on a day which matches standard atmospheric conditions
- The higher the atmospheric pressure, the further the ball moves, essentially due to the greater forces exerted by the more dense air
- *Assumptions*: ball delivered to bounce 3 metres in front of the batting crease, linear interpolation used from experimental results