Aircraft Climb Performance

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Why does aircraft climb performance vary so much?

- Principle reasons are:
  - Aircraft type
  - How heavily loaded it is
  - Atmospheric conditions

Aircraft type and climb performance (1)

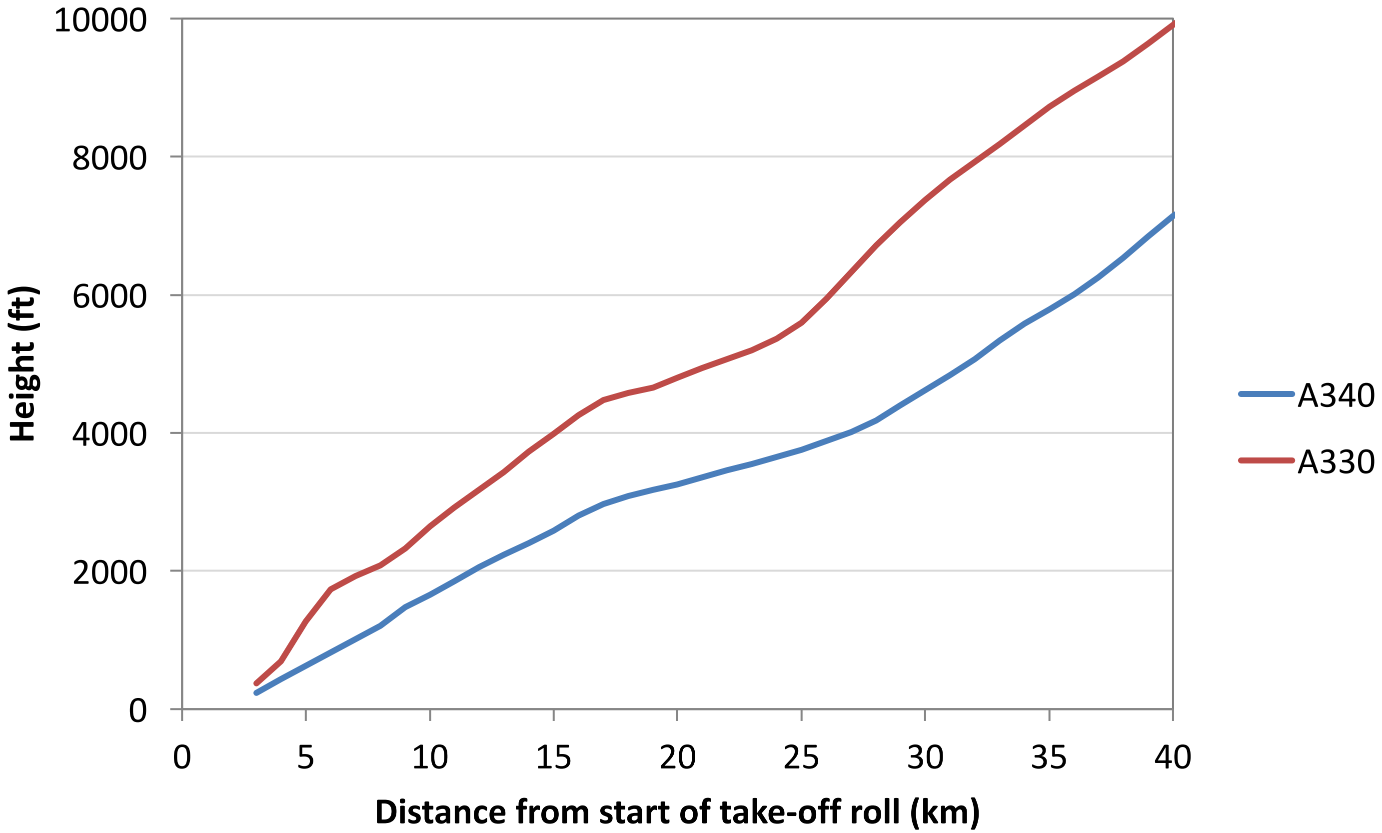
- Initial climb performance (up to 1,000 feet) is strongly influenced by aircraft type, in particular the number of engines it has
- Aviation safety regulations define minimum standards for
  - Take-off runway length
  - Initial climb with one engine failed (one engine inoperative)
  - Initial cruise altitude
- The rules for initial climb are complex:
  - Four phases of initial climb are defined:
    - First segment climb: Surface to 35 feet
    - Second segment climb: 35 feet to 400 feet
    - Third segment climb: 400 feet transition phase
    - Fourth or final segment climb: 400 feet to 1,500 feet

Aircraft type and climb performance (2)

- For every flight, performance has to be checked against all these climb phases, but generally the 2nd segment with one engine failed is considered the most critical operation of all the initial climb segments
- With one engine failed:
  - A 2-engined aircraft has 50% power remaining
  - A 3-engined aircraft has 66% power remaining
  - A 4-engined aircraft has 75% power remaining
- Because a large portion of the remaining power is used to overcome aerodynamic drag, for the engine failed scenario there is little power remaining for climb, but regardless of the number of engines all need to demonstrate positive rates of climb
- But with all engines operating a twin-engined aircraft is ‘over-powered’ compared to a 3 or 4-engined aircraft. **Theoretically, a 2-engined aircraft will be able to climb at 1.8 to 2.2 times the gradient of a 4-engined aircraft, whilst meeting the same initial climb safety requirement.**

2 and 4-engined aircraft climb profiles

- South African Airlines to Johannesburg: A330 vs A340



Aircraft type and climb performance (3)

- Safety regulations define critical take-off speeds:
  - V_1 – decision to abort or go
  - V_2 – initial climb speed: to be reached by 35 feet and maintained to a minimum of 800 feet
- V_2 varies considerably across aircraft types and depending on aircraft load:

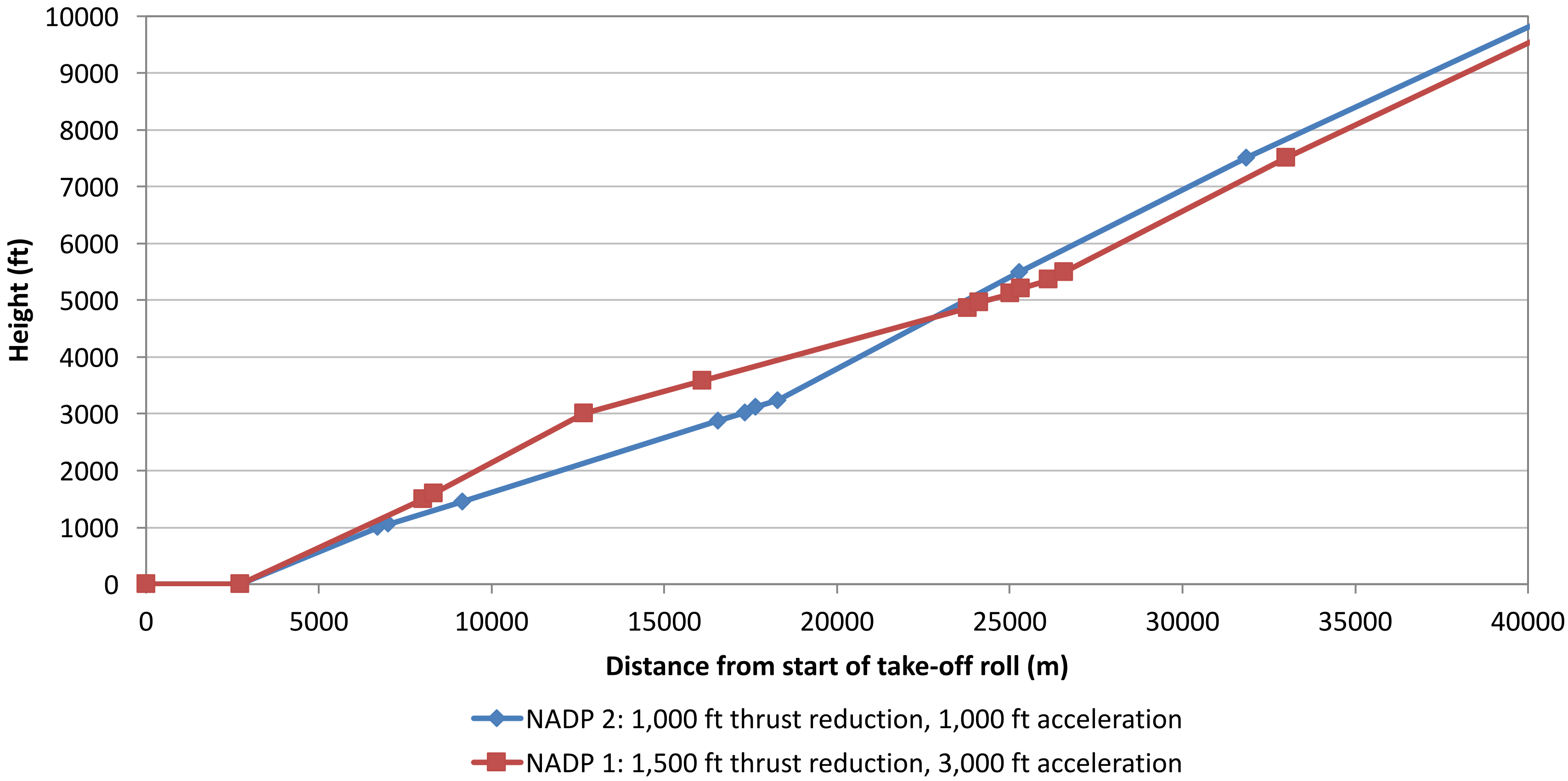
Type	V2 (kt)
A319-131	136
A380-861	151
A380-861	179
B747-400	189
B777-300ER	210
B787-8	178

Acceleration phase

- Aircraft cannot remain as the minimum takeoff speed for ever
- At a minimum of 800 feet, but more normally 1,000 feet, aircraft begin acceleration to a higher speed:
  - Need to accommodate the varying speeds of different aircraft types
  - Transition to more efficient speed (retracting flaps)
  - Facilitate expeditious use of airspace (as directed by the Transport Act 2000 s.70)
- Acceleration naturally takes energy away from climbing reducing the climb rate/gradient
- An aircraft with a lower V_2 speed will need to accelerate for longer
- Delaying acceleration to gain height is a valid noise abatement technique but it doesn't reduce noise overall, it just moves noise from one area to another.

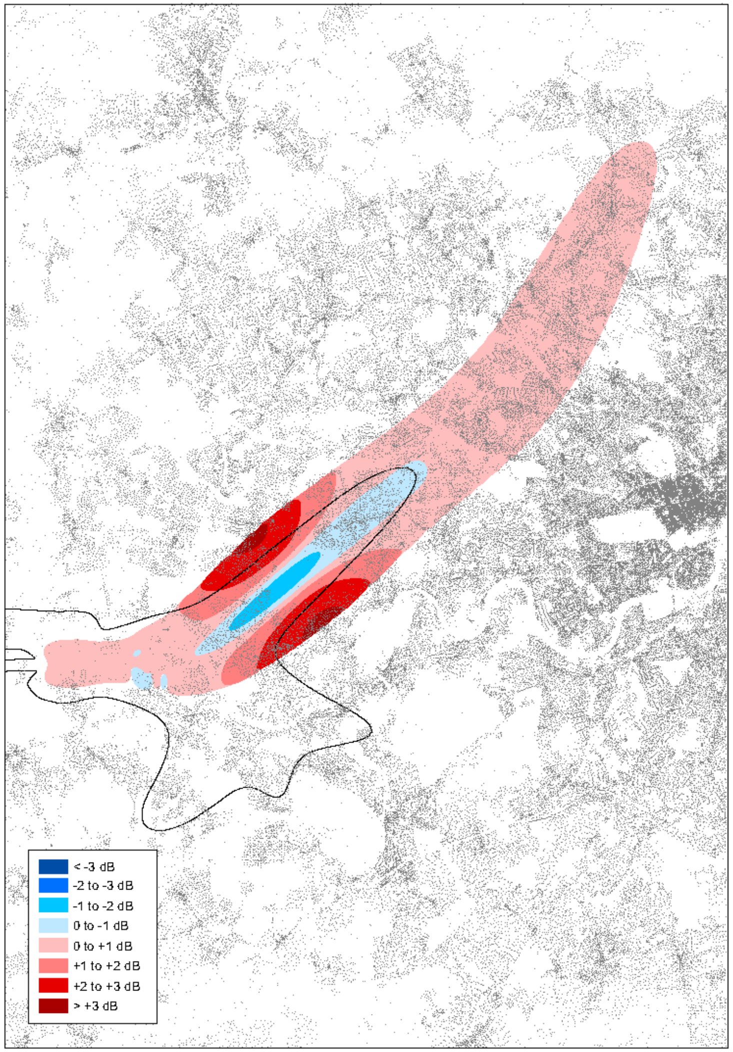
Effect of acceleration phase on climb performance

- Example height profiles for 1,000 feet and 3,000 feet acceleration



Footprints and difference contours

- Blue colours show noise decrease for a delayed acceleration (the higher aircraft)
- Red colours show noise increase for the higher aircraft



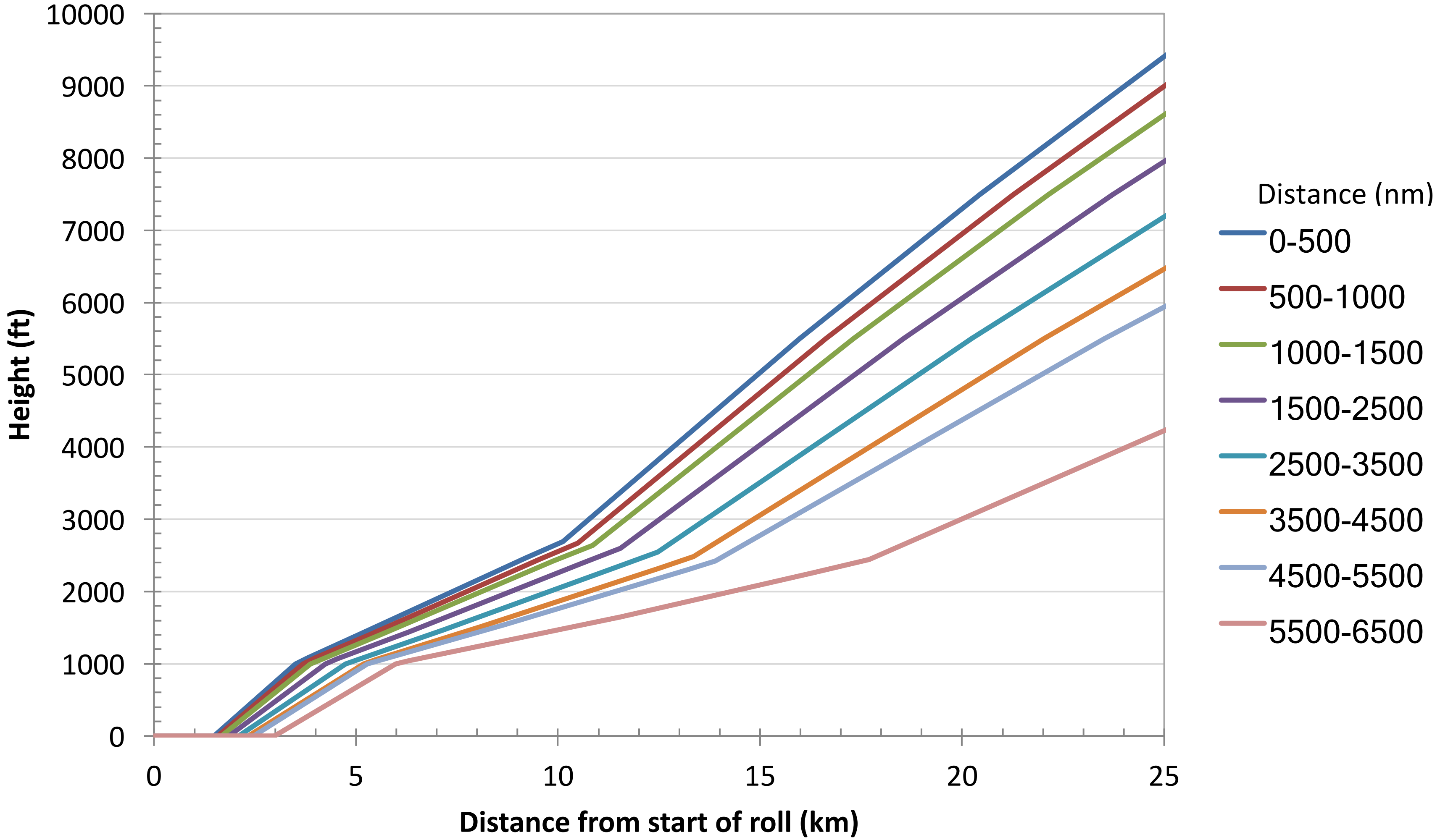
Effects of aircraft load (passengers and fuel)

- For a very long range aircraft, a substantial proportion of the mass is fuel, not passengers/cargo:

Component	Percent of total mass
Operating Empty Weight	51%
Typical payload (passengers/bag & cargo)	14%
Fuel	36%
Total	100%

- Fuel load and therefore distance flown (destination) is therefore the greater factor affecting aircraft mass on a day to day basis

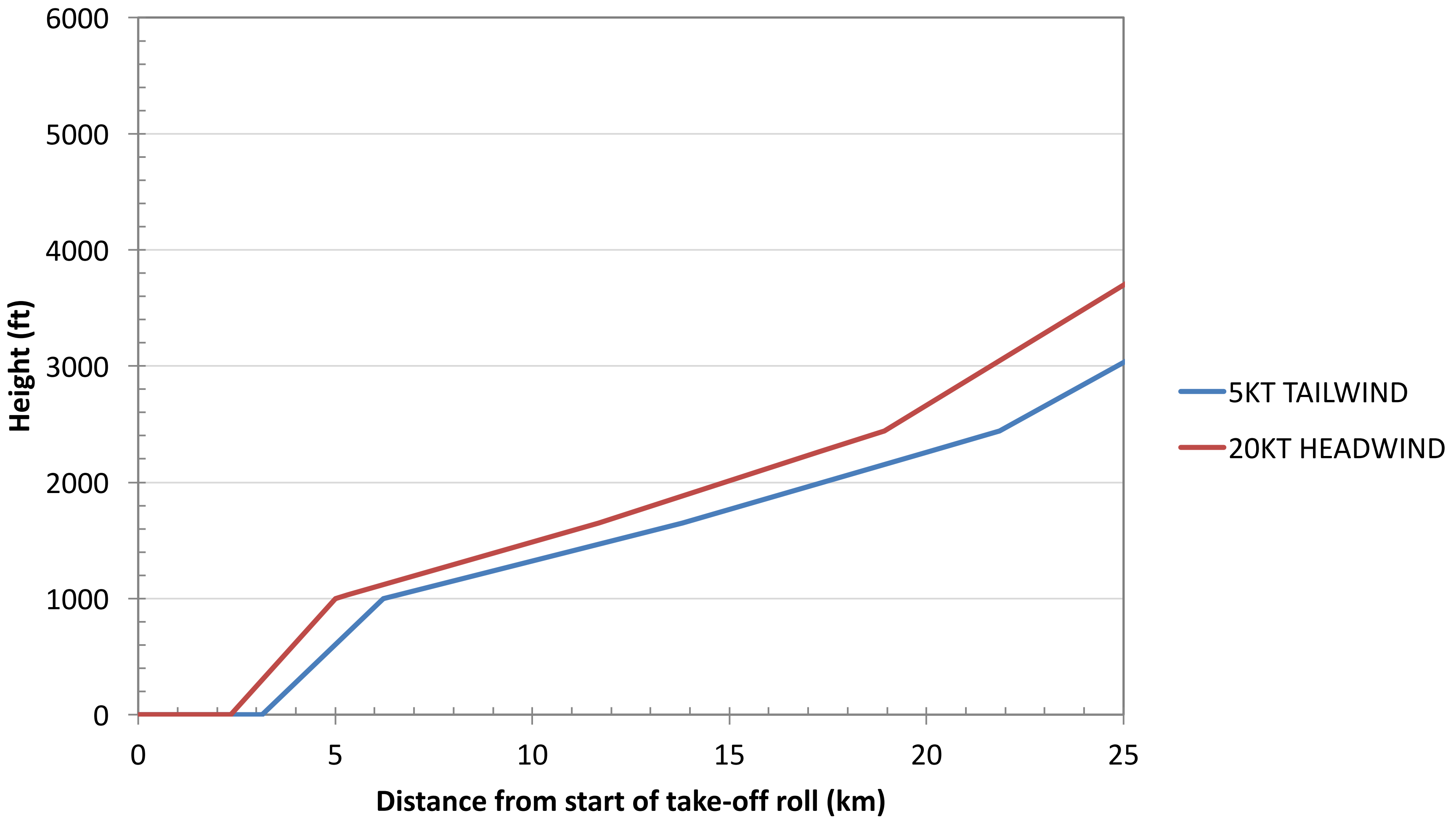
Effect of aircraft mass on aircraft height



Atmospheric Effects

- Warmer air is less dense and requires higher take-off speeds, higher climb speeds to ensure safe operation reducing climb performance
- Although rare occurrences, above approx 30degC engine power has to be decreases to preserve safe operation of the engine further reducing climb performance
- Wind also effects climb performance. The stronger the head wind the better the rate of climb.
- Westerly preference sometimes requires operation with a tailwind, exacerbating the potential effect of wind.

Effect of wind on climb performance



Questions?