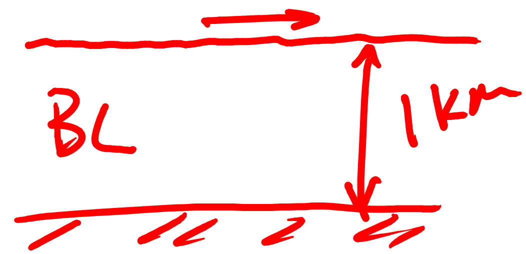
Wind Resource



C. Atmospheric Boundary Layer

WIND TURBINES IMMERSED IN THE BL

1. Why is it Important to Wind Energy?

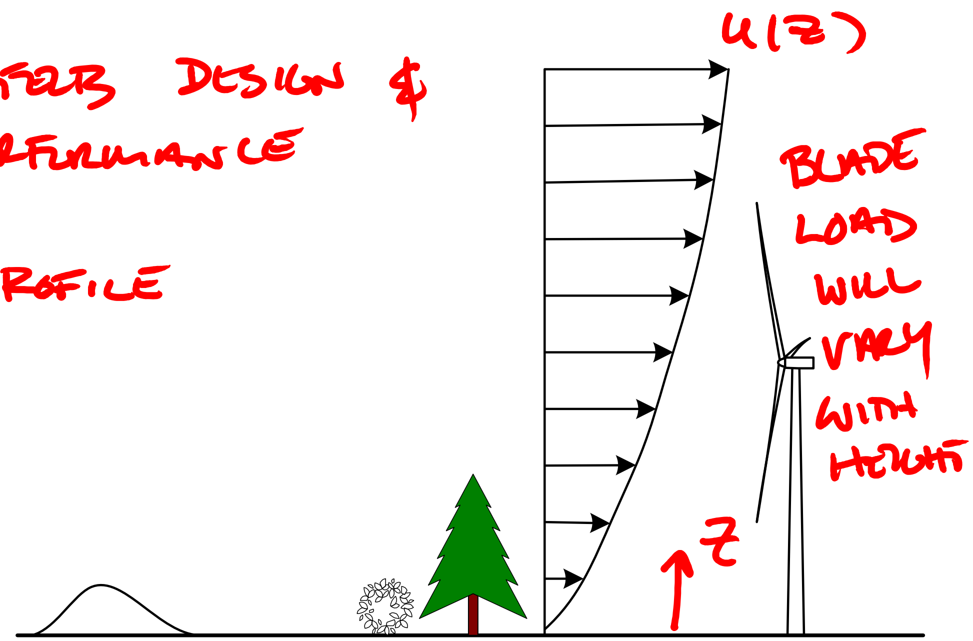
VERTICAL VARIATION OF WIND WITH HEIGHT

WIND SHEAR
TURBULENT WIND

AFFECT DESIGN & PERFORMANCE

FACTORS THAT AFFECT WIND PROFILE

- TERRAIN
- VEGETATION
- STABILITY



OUR KNOWLEDGE OF THE ATMOSPHERIC BL IS NOT AS GOOD AS WE'D LIKE IT TO BE

Wind Resource

C. Atmospheric Boundary Layer

2. Wind Variation with Height (MEAN)

COMPLEX LAWS AVAILABLE FOR SIMPLE GEOMETRIES

MOST ARE NOT REPRESENTATIVE OF REAL WIND PROFILES

STICK TO RELATIVELY SIMPLE PROFILES

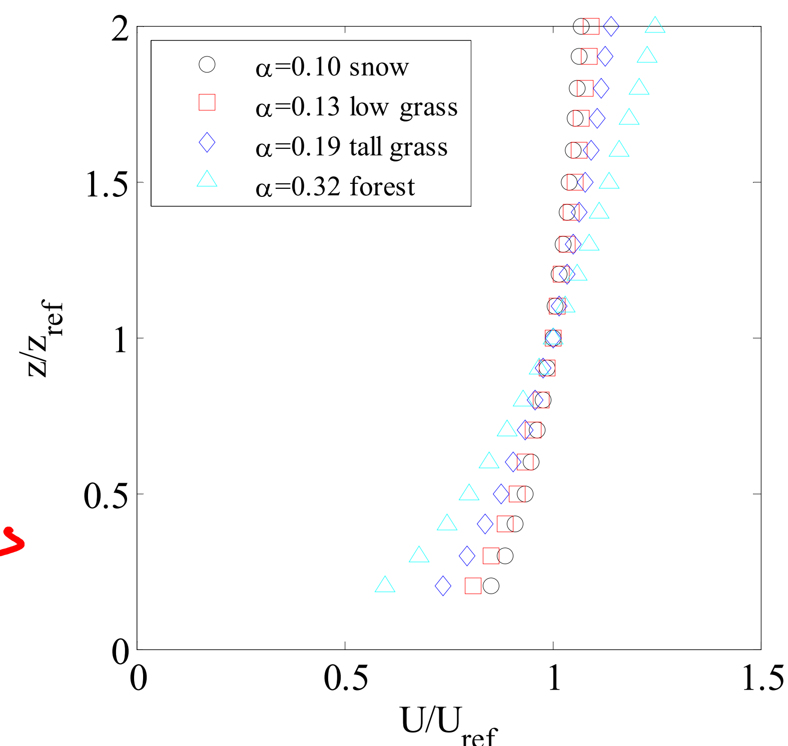
a. Power Law

$$\frac{U}{U_{ref}} = \left(\frac{z}{z_{ref}}\right)^{\alpha}$$

U_{ref} IS AT z_{ref}

α IS POWER EXPONENT

← CORRELATED WITH ROUGHNESS



Wind Resource

C. Atmospheric Boundary Layer

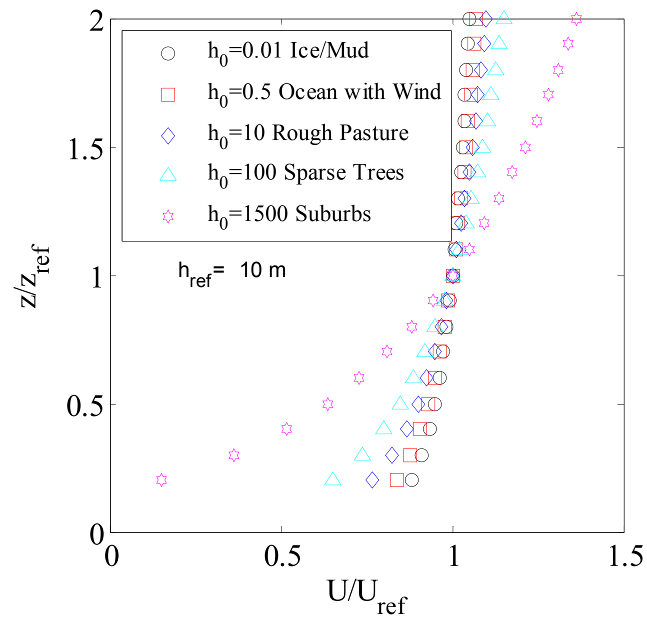
2. Wind Variation with Height

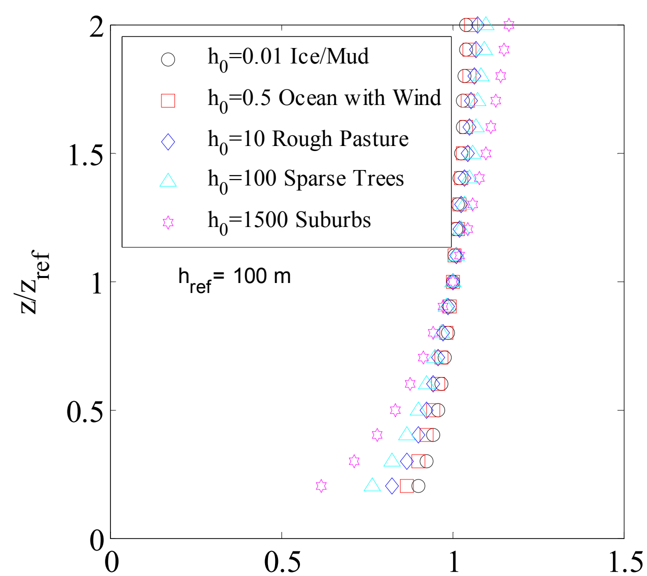
b. Logarithmic Law

USING SOME SEMI-EMPIRICAL ARGUMENTS A LOGARITHMIC PROFILE CAN BE ARGUED

$$\frac{U}{U_{ref}} = \frac{\ln(z/z_0)}{\ln(z_{ref}/z_0)}$$

z_0 IS ROUGHNESS LENGTH





Wind Resource

C. Atmospheric Boundary Layer

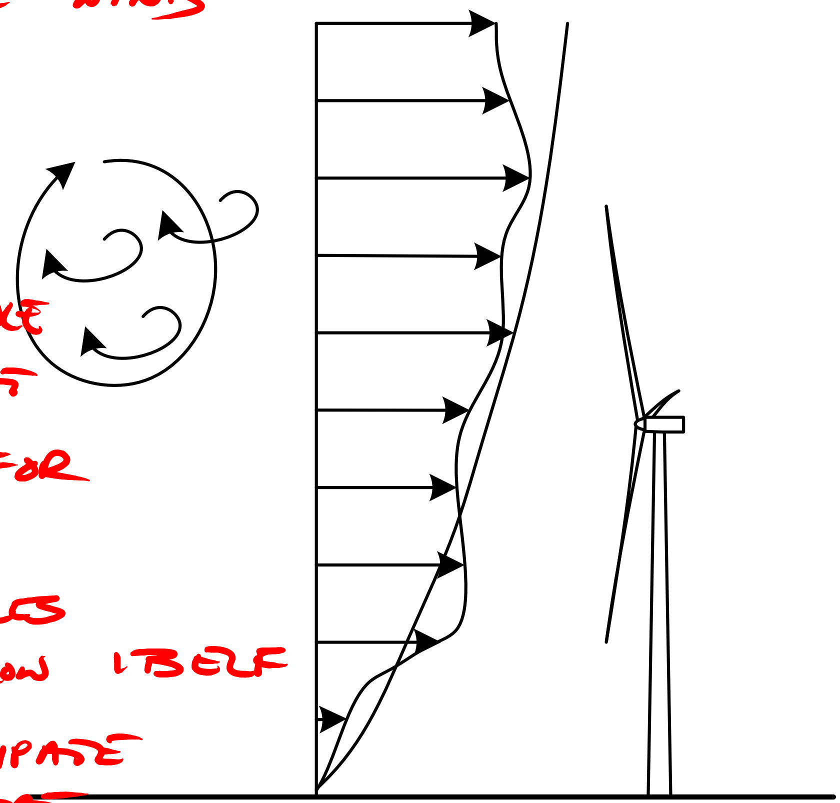
3. Turbulence

RANDOM FLUCTUATIONS IN THE WIND VELOCITY AND DIRECTION

SOURCE OF TURBULENCE IS THE WIND ITSELF

ENERGY THAT PASSES INTO TURBULENCE EVENTUALLY DISSIPATES AS HEAT
→ IMPORTANT MECHANISM FOR DISSIPATING WIND

TURBULENCE COMES IN MANY SCALES
LARGEST → ORDER OF THE FLOW ITSELF
SMALLEST → SCALES THAT DISSIPATE ENERGY INTO HEAT



TURBULENCE IS GREATLY AFFECTED BY SURFACE IT INTERACTS WITH

Wind Resource

C. Atmospheric Boundary Layer

3. Turbulence

SINCE TURBULENCE IS RANDOM, IT CAN'T BE PREDICTED

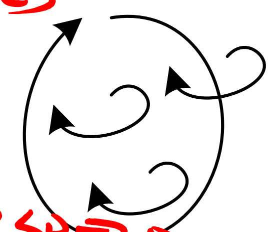
TURBULENCE CAN BE CHARACTERIZED STATISTICALLY

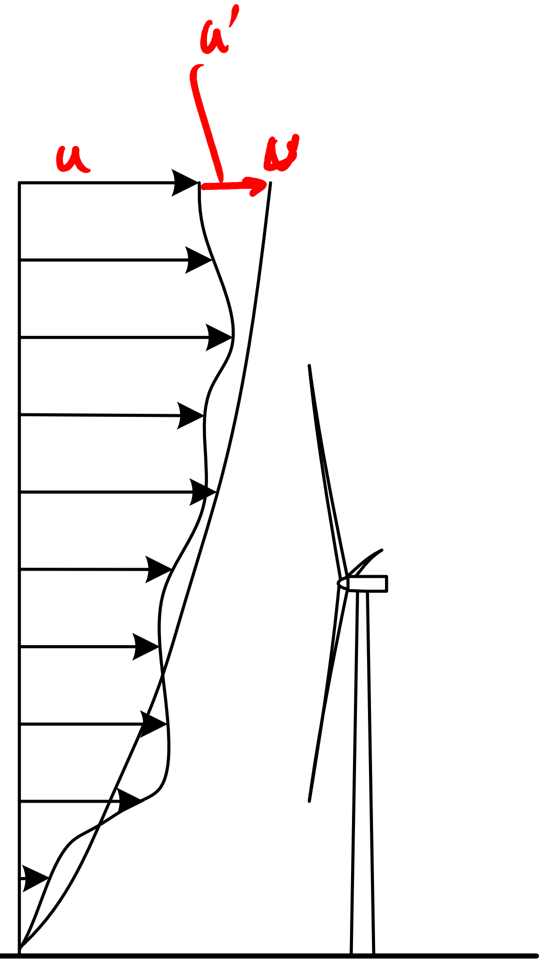
$$u = U + u'$$

u' – FLUCTUATING WIND SPEED

U – MEAN WIND SPEED

u – INSTANTANEOUS WIND SPEED





STATISTICALLY CHARACTERIZE THE WIND

MEAN – AVERAGE OVER SOME PERIOD

$$U = \frac{1}{T}\int_0^T u(t)\,dt \qquad U = \frac{1}{N}\sum_{i=1}^{N} u_i$$

CONTINUOUS DISCRETE

Wind Resource

OTHER DESCRIPTIONS

PROBABILITY DENSITY FUNCTION

INTEGRAL TIME & LENGTH SCALES $\rightarrow u$

POWER SPECTRAL DENSITY

C. Atmospheric Boundary Layer

3. Turbulence

VARIANCE – AVERAGED SQUARE FLUCTUATION

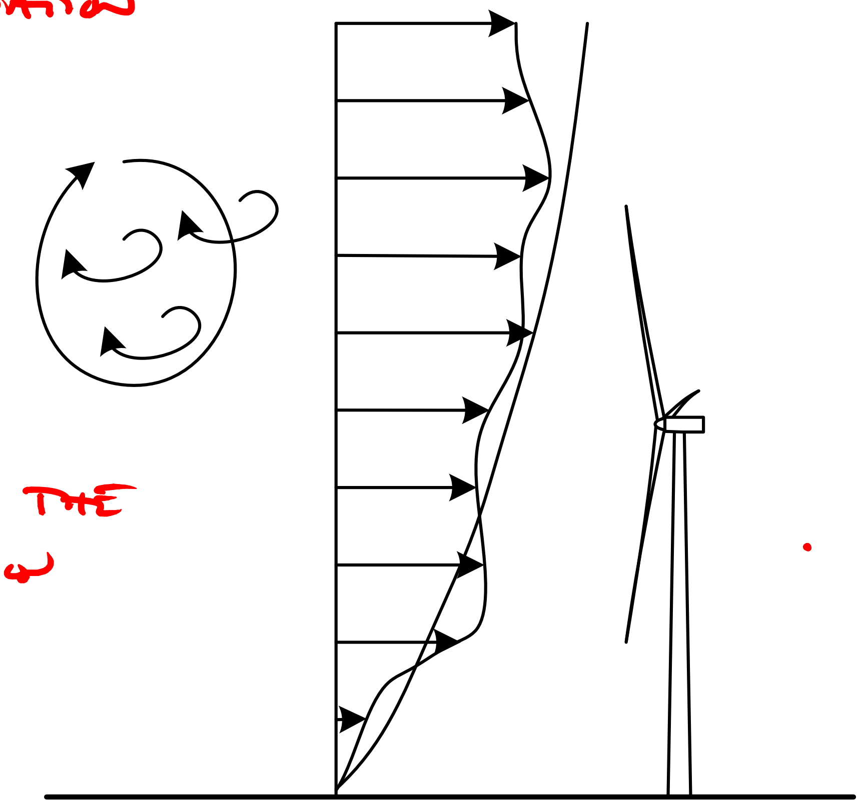
$$\frac{1}{T}\int_0^T u'(t)\,dt = 0$$

$$VAR(u) = \frac{1}{T}\int_0^T u'^2(t)\,dt = \frac{1}{N-1}\sum_{i=1}^{N} u_i'^2$$

VARIANCE IS THE SQUARE OF THE STANDARD DEVIATION

OFTEN NON-DIMENSIONALIZE

$$TI = \frac{\sqrt{VAR(u)}}{U} = \frac{S_u}{U}$$



REMEMBER WIND HAS 3 COMPONENTS, v & w CHARACTERIZED SIMILARLY