National Applied Research Laboratories

Lidar observation of surface wind profiles in Changhua Coastal Industrial Park

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Outline of contents

- Introduction
- Site descriptions
- Principle of wind Lidar
- Observation results
- Conclusions

Aim of this study

- To observe seasonal variations
- Characteristics of wind profiles - wind speed and turbulence intensity, directional difference, and inclination
- Micro-meteorology
- Engineering and wind energy application

Observation site

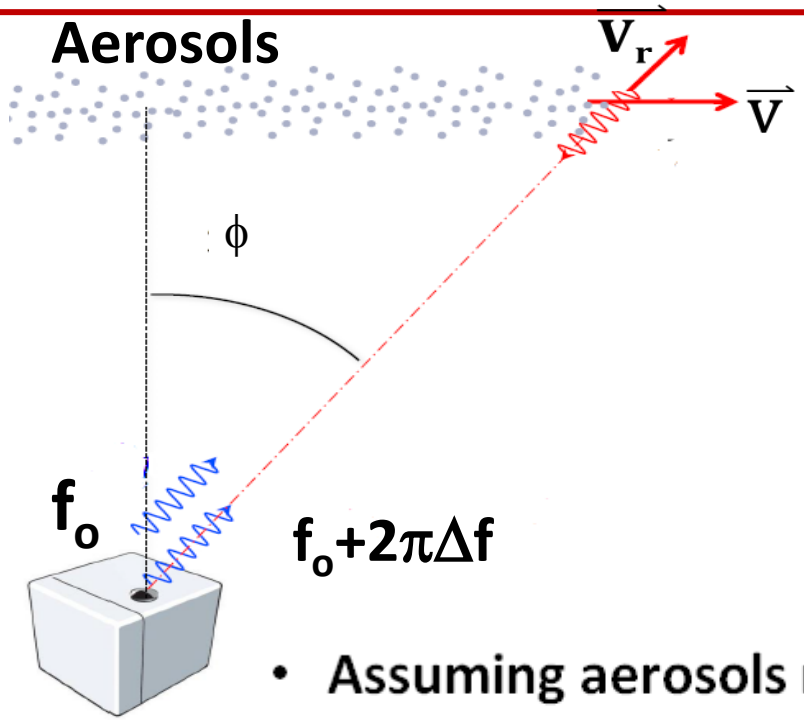
- **Changhua Coastal Industrial Park**

- **Wind turbines surrounded**

- **Lay out of instruments**

Principle of Lidar

- **Windcube v2**



- ✓ **Short range: 40-200(290) m**
- ✓ **Observation 12 range gates simultaneously**
- ✓ **Wave length 1543 nm**

- **Assuming aerosols moving with wind**

Radial velocity

$$V_r = \frac{\lambda \Delta f}{2}$$

Δf: Doppler frequency shift

Velocity retrieving

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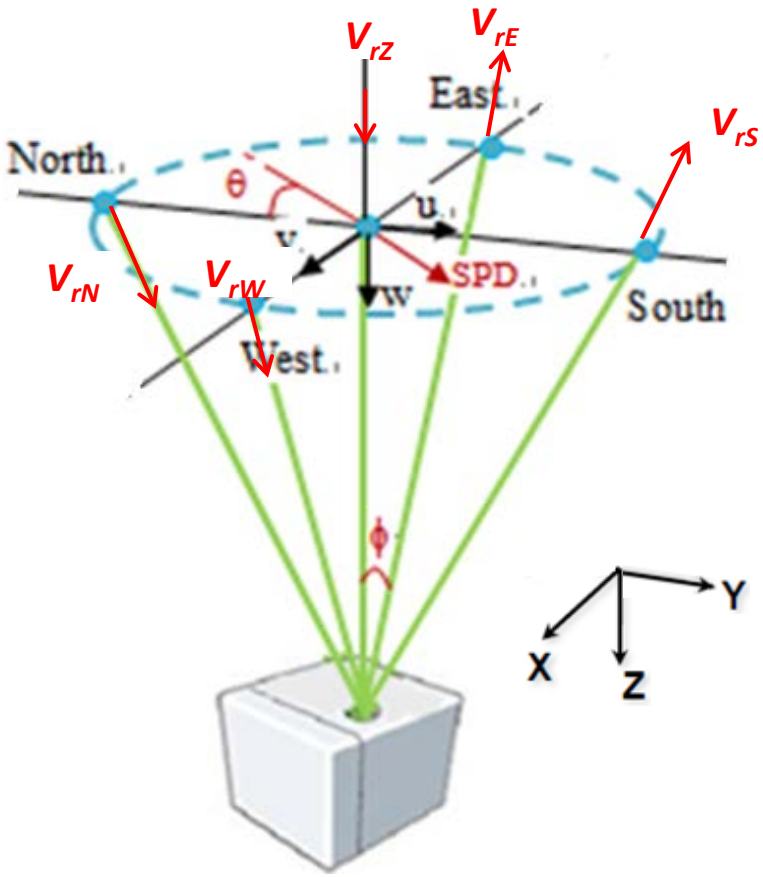
- **Lidar scanning**



$$u = \frac{Vr_N - Vr_s}{2sin\phi},$$

$$v = \frac{Vr_E - Vr_W}{2sin\phi},$$

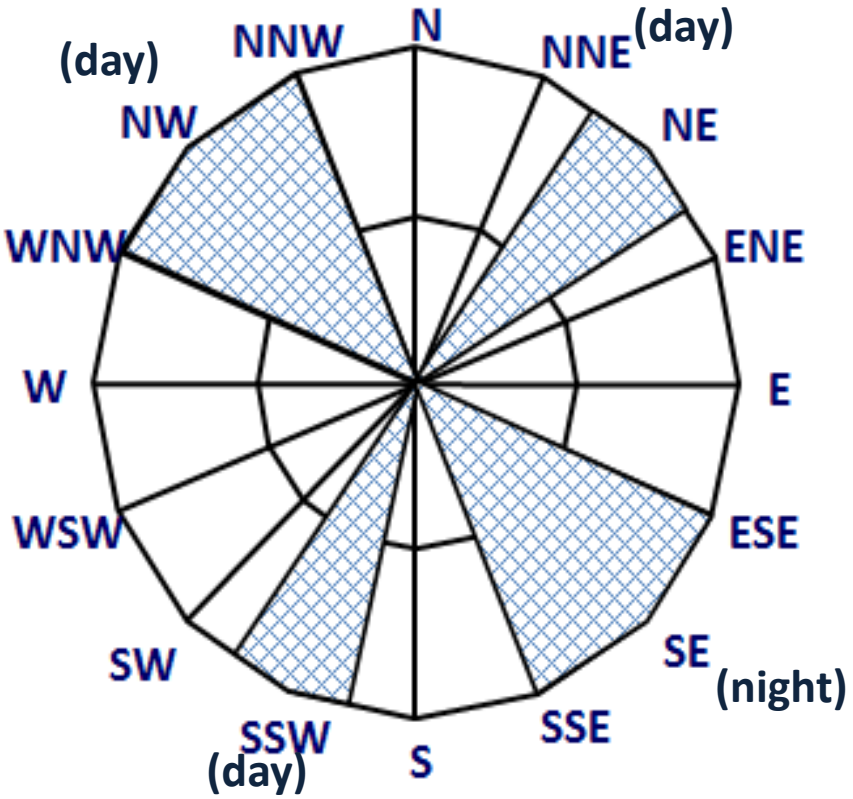
$$w = Vr_z$$

Wind speed $\mathbf{U} = \sqrt{u^2 + v^2}$

Wind direction $\theta = tan^{-1}\left(\frac{v}{u}\right)$

Data processing

- **Wind direction selected inconsideration the influence of the turbine wakes**

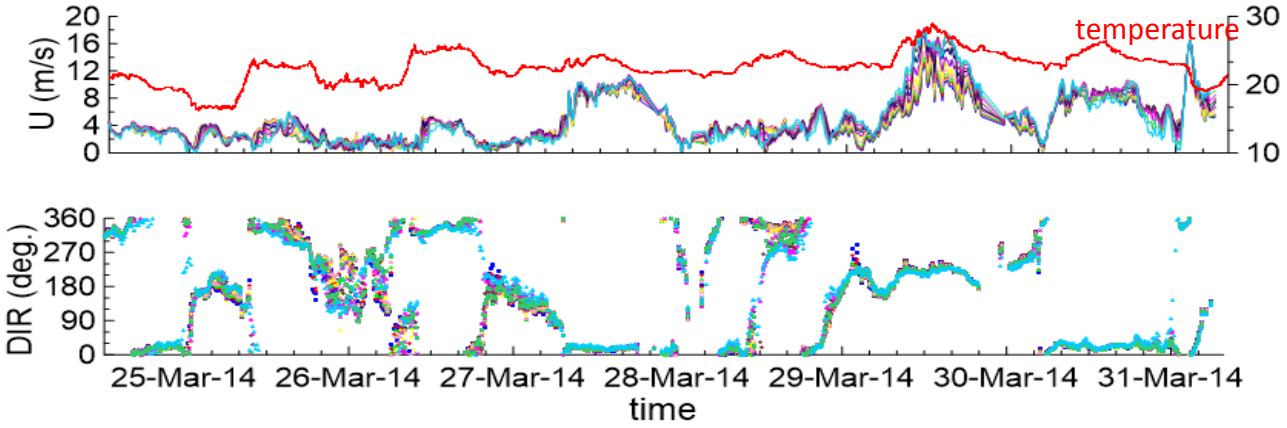


- **Bin averaged**

U_R=2-4, 4-6, 6-8……, 22-24 m/s

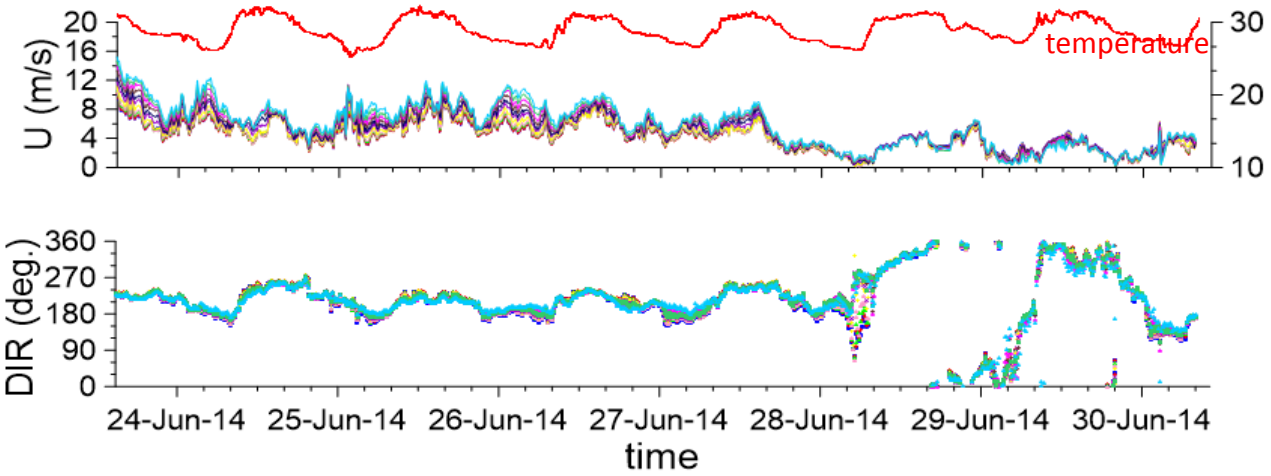
Time series (I)

- **Spring, 3/24-3/31, 2014**



- **Mixed with northerly and southerly wind direction**

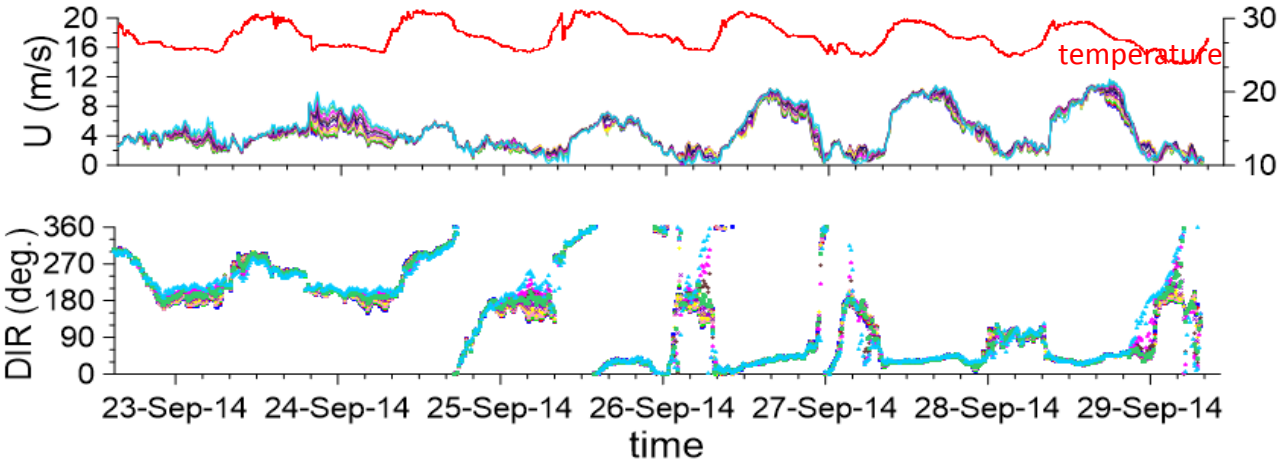
- **Summer, 6/23-6/30**



- **Weak wind in summer**

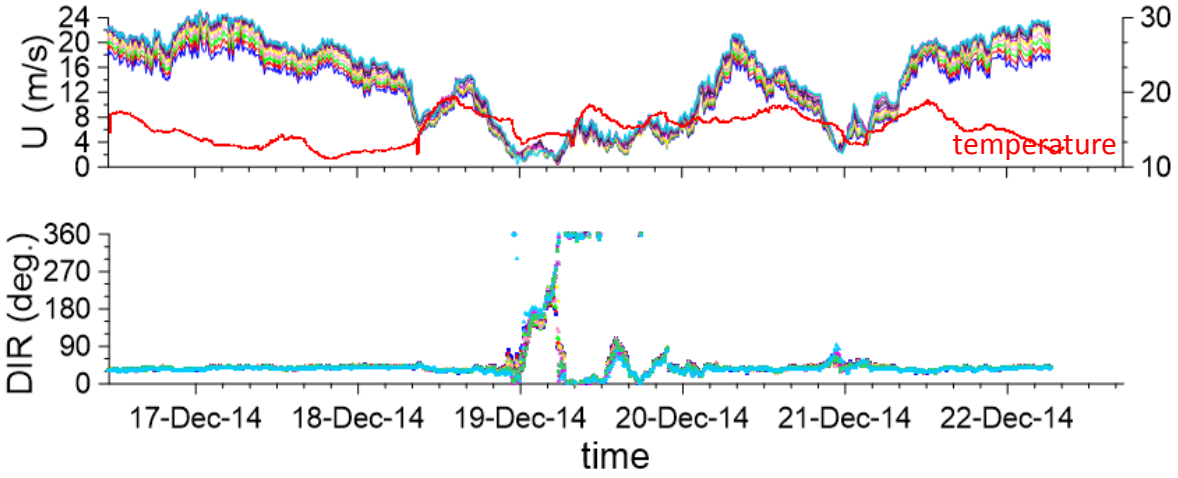
Time series (II)

- **Autumn, 9/22-9/29**



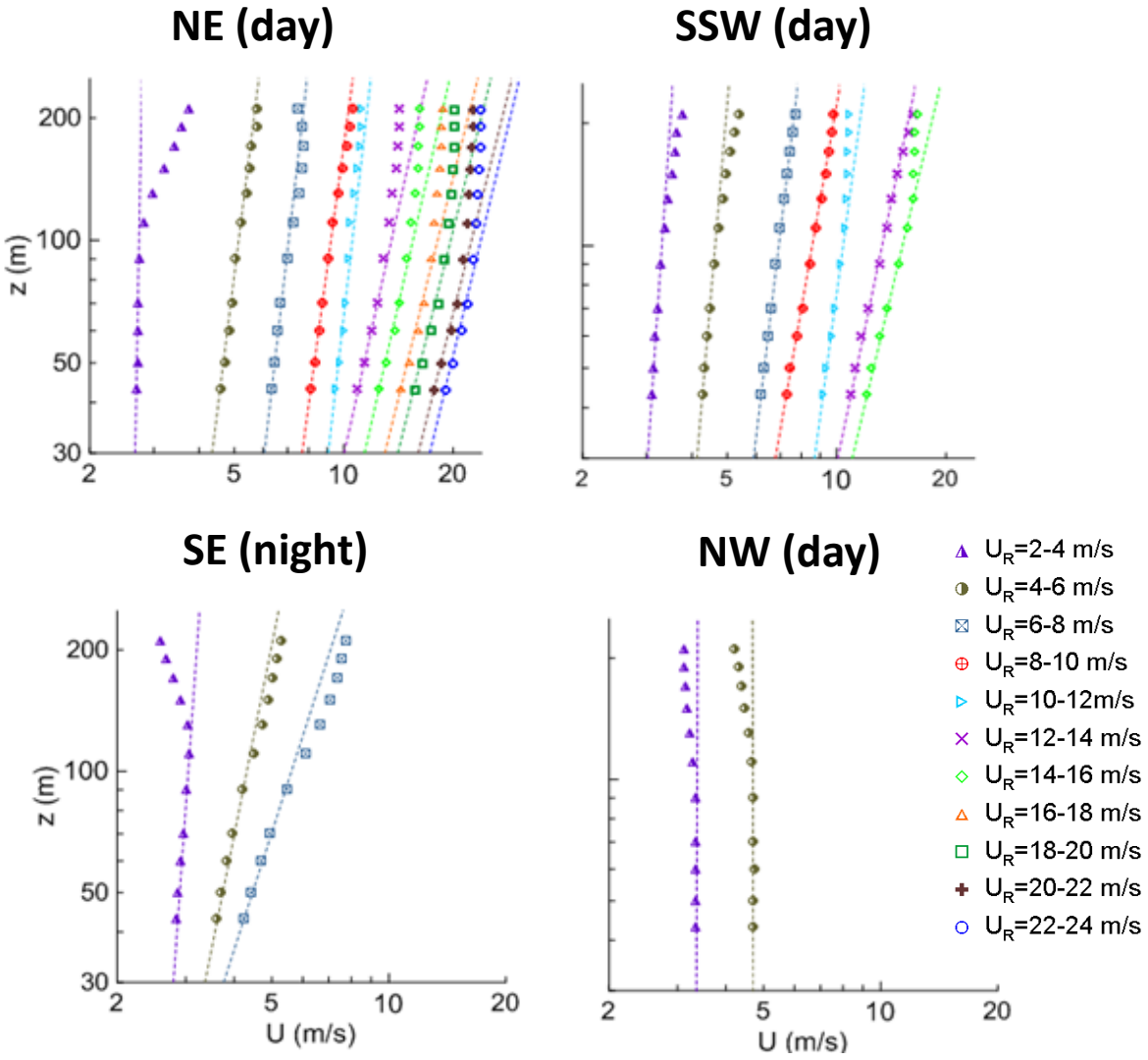
- **Diurnal cycle**

- **Winter, 12/15-12/22**



- **Strong wind and steady wind direction**

Profile of wind speed



- **Power law**

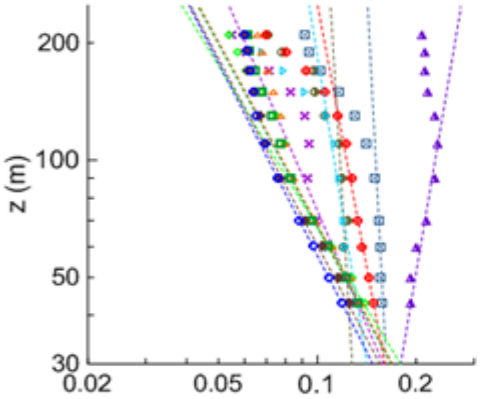
$$\frac{U(z)}{U_r} = \left(\frac{z}{z_r}\right)^{\alpha}$$

α: power exponent

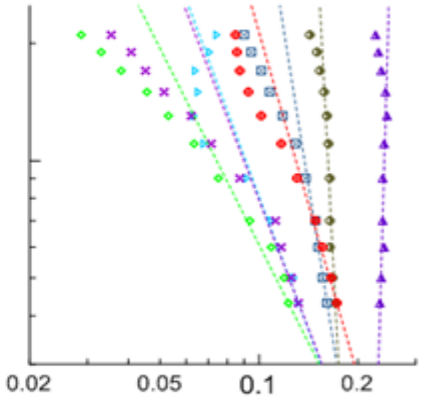
- **0.02~0.28, increase with the wind speed**
- **Thermal effect for the weak wind**
- **Negative value for onshore wind**

Profile of turbulence intensity

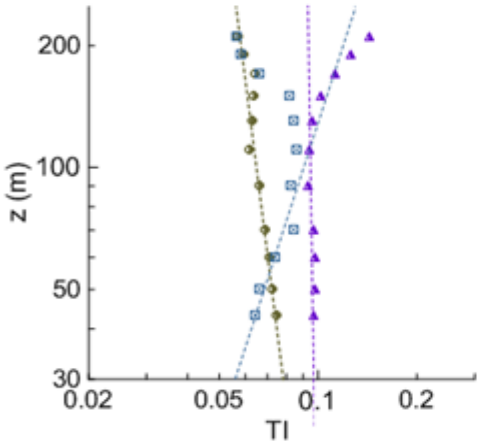
NE (day)



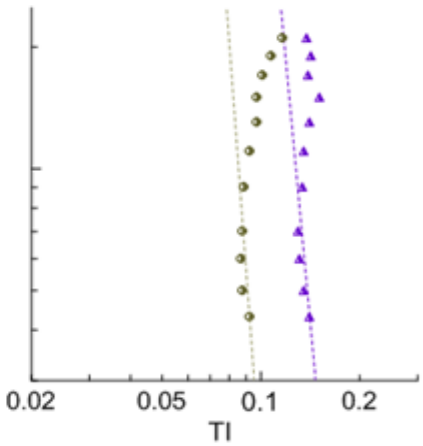
SSW (day)

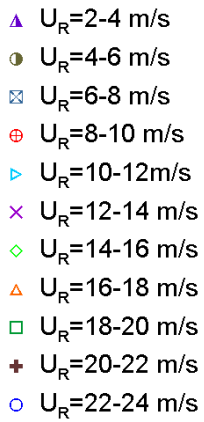


SE (night)



NW (day)



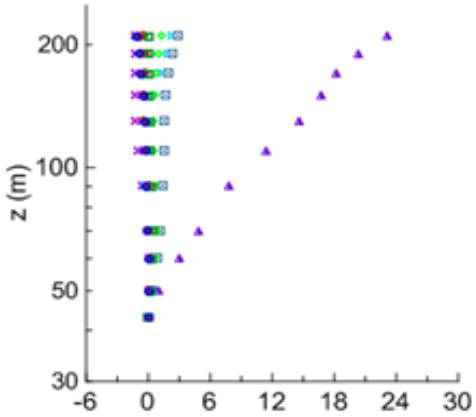


$$TI(z) = \frac{U_\sigma(z)}{\bar{U}(z)}$$

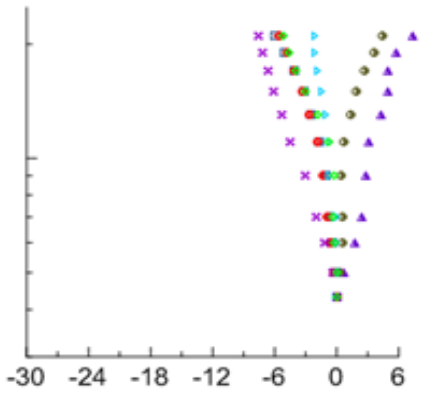
- Turbulence intensity decreases with the increase of height
- Stabilize at night

Profile of directional difference

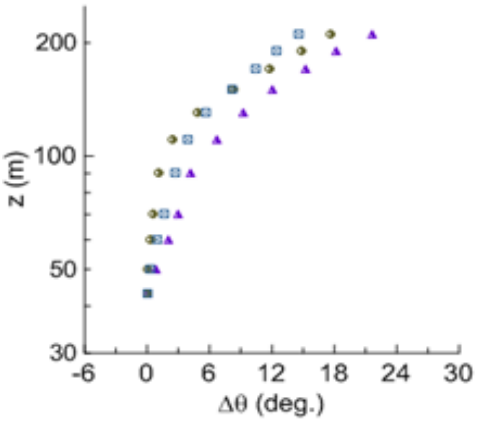
NE (day)



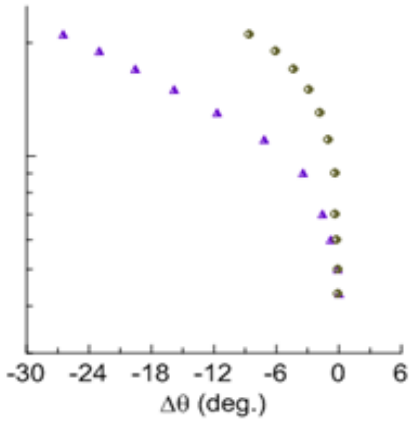
SSW (day)



SE (night)



NW (day)

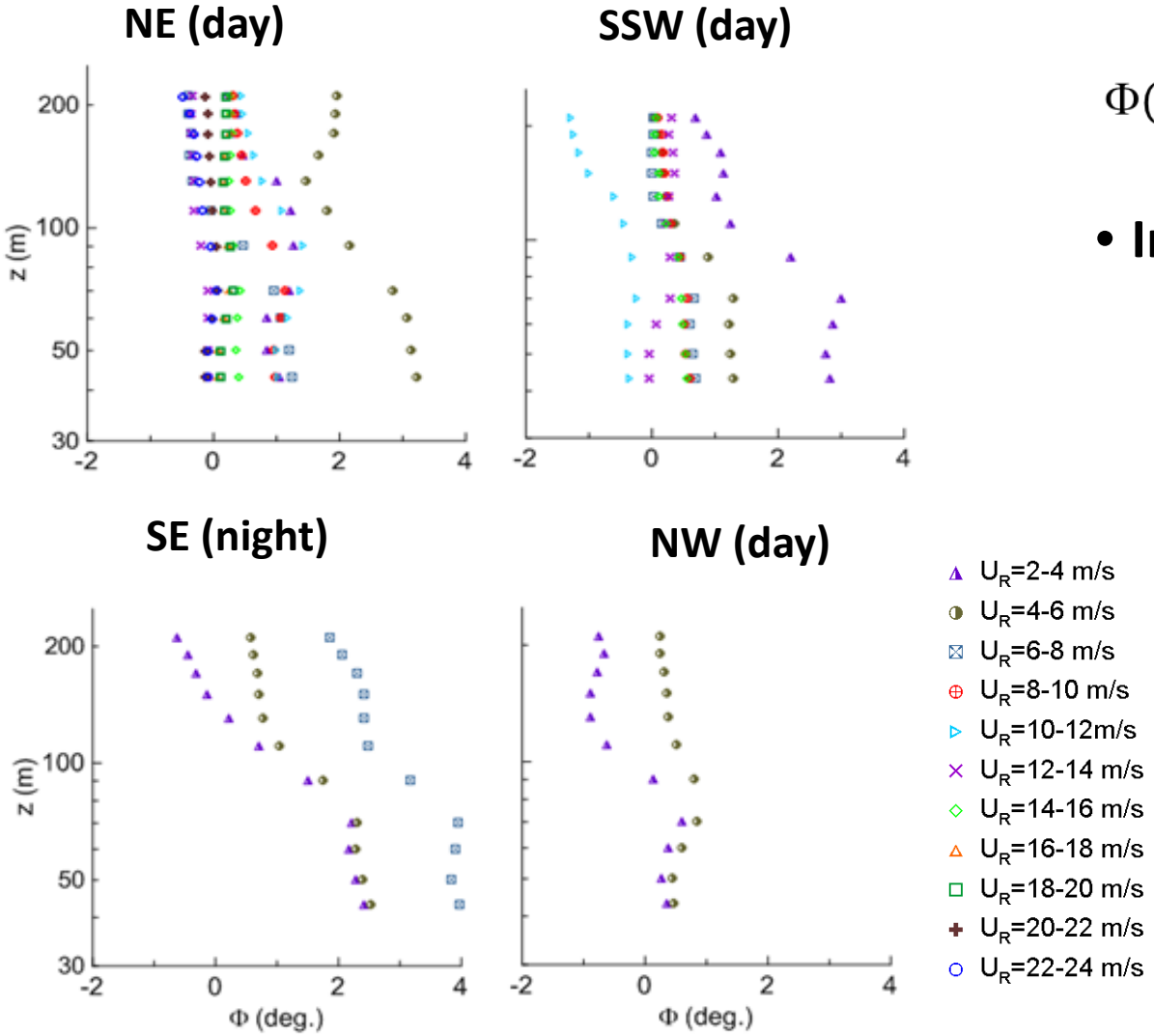


$$\Delta\theta(z) = \theta(z) - \theta(40)$$

- **Significantly directional difference for the weak wind**

- U_R=2-4 m/s
- U_R=4-6 m/s
- U_R=6-8 m/s
- U_R=8-10 m/s
- U_R=10-12m/s
- U_R=12-14 m/s
- U_R=14-16 m/s
- U_R=16-18 m/s
- U_R=18-20 m/s
- U_R=20-22 m/s
- U_R=22-24 m/s

Profile of inclination



$$\Phi(z) = tan^{-1}\left(\frac{\overline{W}(z)}{\overline{U}(z)}\right)$$

- **Insignificant inclination**

Conclusions

- Significantly seasonal variations in wind speed and direction and affected by daily thermal effect
- Power law described for the rage below 120 m in all the wind conditions
- Different shape of wind profiles for the weak wind as well as sea-land breeze
- Long-term observation is required for the wind energy industry using Lidar or a mast

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Thank you for your attention!