Investigating adjustment of wind profile formulas to a reference height using observation records at the Ieodo Ocean Research Station

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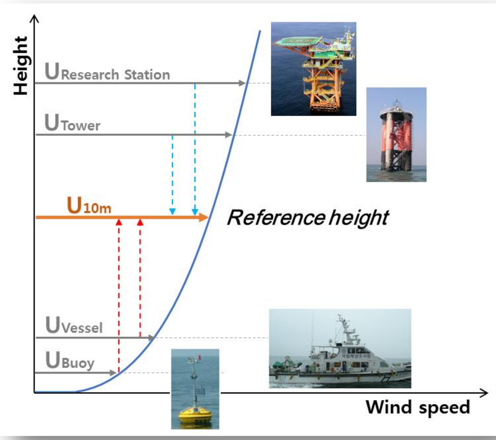
Introduction

Conventionally, **winds** measured **at various heights** at sea are **adjusted to a 10-m reference height**. These converted data are used to calculate wind stress and heat flux at the sea surface and to conduct validation and verification of winds simulated from meteorological models and measured from spaceborne scatterometer.



This is a preliminary study on adjustment of wind speeds measured at the Roof Deck of the **Ieodo Ocean Research Station** in order to service wind speeds at a 10-m reference height.

Ieodo Ocean Research Station

The **Ieodo Ocean Research Station** (Ieodo ORS) is situated **on submarine rock** called **Ieodo** in the East China Sea. The Korea Hydrographic and Oceanographic Agency (KHOA) has been running these ORSs since 2007. The KHOA has been conducting a program of "IORS field trip" since 2014 in order to further enhance it to be an international observation station.

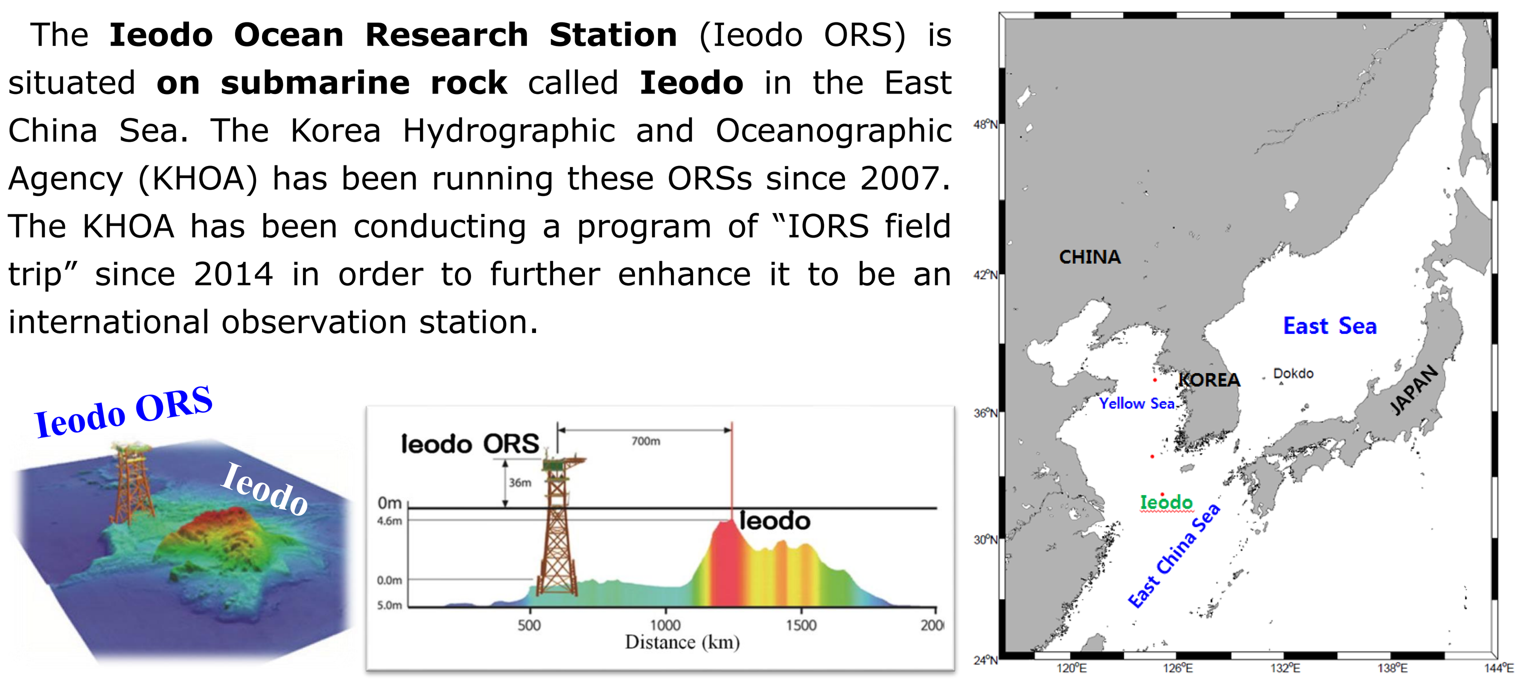
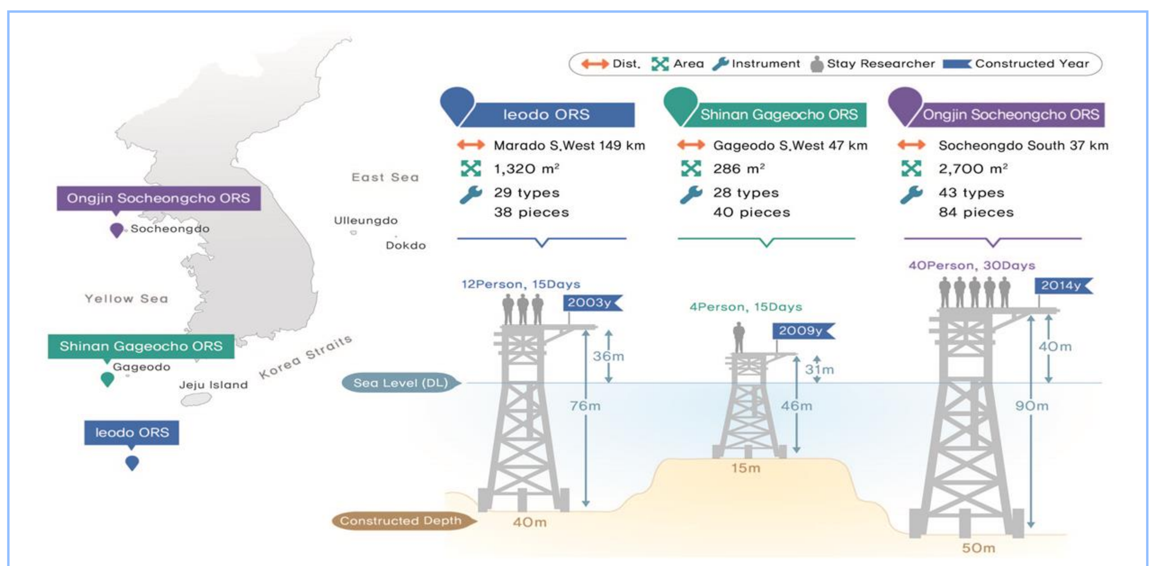


Figure 1. Location of the Ieodo Ocean Research Station.

Ocean Research Stations running by KHOA



The Ieodo, Shinan Gageocho and Ongjin Socheongcho Ocean Research Stations are located in the open seas including jurisdictional sea areas of Korea and are used to conduct oceanographic, meteorological and environmental observations.

Observation

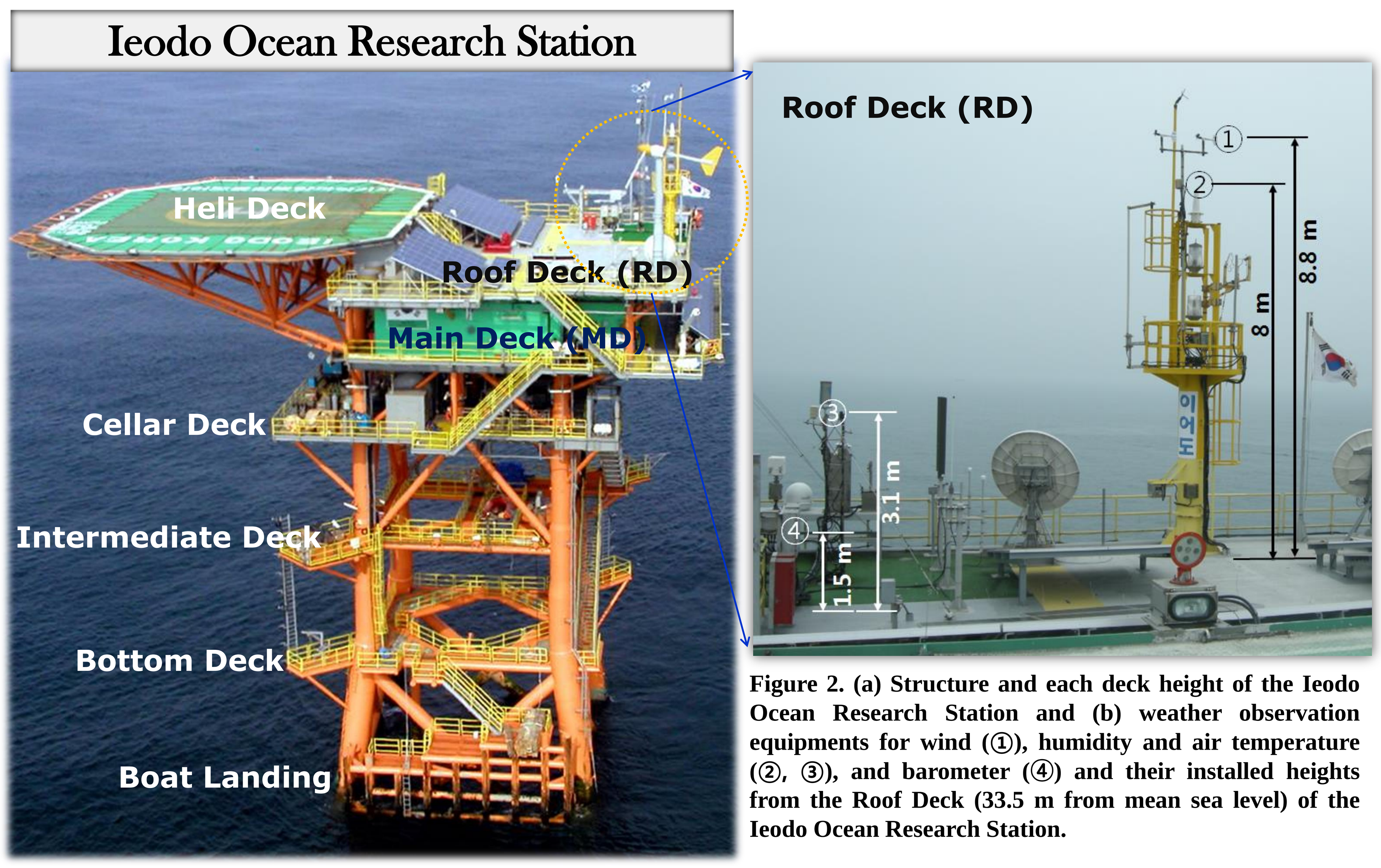


Figure 2. (a) Structure and each deck height of the Ieodo Ocean Research Station and (b) weather observation equipments for wind (①), humidity and air temperature (②, ③), and barometer (④) and their installed heights from the Roof Deck (33.5 m from mean sea level) of the Ieodo Ocean Research Station.

Location	Sensor	Manufacturer	Used data
RD ①	**Wind** (MODEL 05106)	R.M. YOUNG	A-year-long (2015) hourly records
RD ②	**Humidity & Temperature** (HMP155)	VAISALA	
RD ④	**Barometer** (PTB210B)	VAISALA	
MD	**Sea level height** (Microwave radar)	RS Aqua	
5 m below sea surface	**Sea surface temperature** (CT3919)	AANDERAA	

Table 1. Meteorological and oceanographic sensors installed at the Ieodo Ocean Research Station.

Methodology

- We have tested three well-known empirical neutral wind profile formulas and the logarithmic model with stability function to examine their applicability into 10-m reference level wind speeds.
- we also compared each wind speed data converted from the four neutral wind profile formulas with ASCAT (Advanced SCATterometer) data, which are proved by NASA (http://podaac.jpl.nasa.gov/).

Table 2. Wind profile formulas for adjusting sea winds measured at the Roof Deck (42.3 m) of the Ieodo Ocean Research Station to a 10-m reference height

Type (Ref.)	Formulas	Parameters	Note
Power Law (Spera and Richards, 1979)	$U_{10}^{PW} = U_z \left(\frac{z_{10}}{z}\right)^p$	$p = 0.11$	**Neutral wind**
Logarithmic Profile (Large et al., 1995)	$U_{10}^{LV} = U_z \left[\frac{1}{1+\sqrt{C_{d10}^{V83}}/\kappa \; ln\left(\frac{z}{z_{10}}\right)}\right]$	$\kappa = 0.4$ $C_{d10}^{V83} = 10^{-3}[2.717U_{10} + 0.142(U_{10})^2 + 0.0764(U_{10})^3$	
Logarithmic Profile (Smith, 1988)	$U_{10}^{SM} = \frac{u_*}{\kappa} ln\left(\frac{10}{z_0}\right)$	$z_0 = \left(0.011\frac{{u_*}^2}{g}\right) + \left(0.11\frac{v}{u_*}\right)$ $u_* = \frac{\kappa U_z}{ln(z/z_0)}$ $\nu = 1.5\times10^{-5} m^2 s^{-1}$	
	$U_{10}^{SM}(\nu(T)) = \frac{u_*}{\kappa} ln\left(\frac{10}{z_0}\right)$	$\nu(T) = 1.326e^{-5}(1 + 6.542e^{-5} + 8.301e^{-6}T^2 - 4.84e^{-9}T^3)$	
LKB model (Liu and Tang, 1996)	$U_{10}^{LKBn} = \frac{u_{**}}{\kappa} ln\left(\frac{10}{z_0}\right)$	$z_0 = \left(0.011\frac{{u_{**}}^2}{g}\right) + \left(0.11\frac{v}{u_{**}}\right)$ $u_{**} = \frac{\kappa U_z}{ln\left(\frac{z}{z_0}\right) - \varphi_U}$	
	$U_{10}^{LKBs} = \frac{u_{**}}{\kappa}\left[ln\left(\frac{10}{z_0}\right) - \varphi_U\right]$	$z_0 = \left(0.011\frac{{u_{**}}^2}{g}\right) + \left(0.11\frac{v}{u_{**}}\right)$ $u_{**} = \frac{\kappa U_z}{ln\left(\frac{z}{z_0}\right) - \varphi_U}$ $\varphi_U(z, U, T_a, T_s, RH, P)$	**Wind including stability effect**

Adjustment of Ieodo ORS wind speed data to a reference height

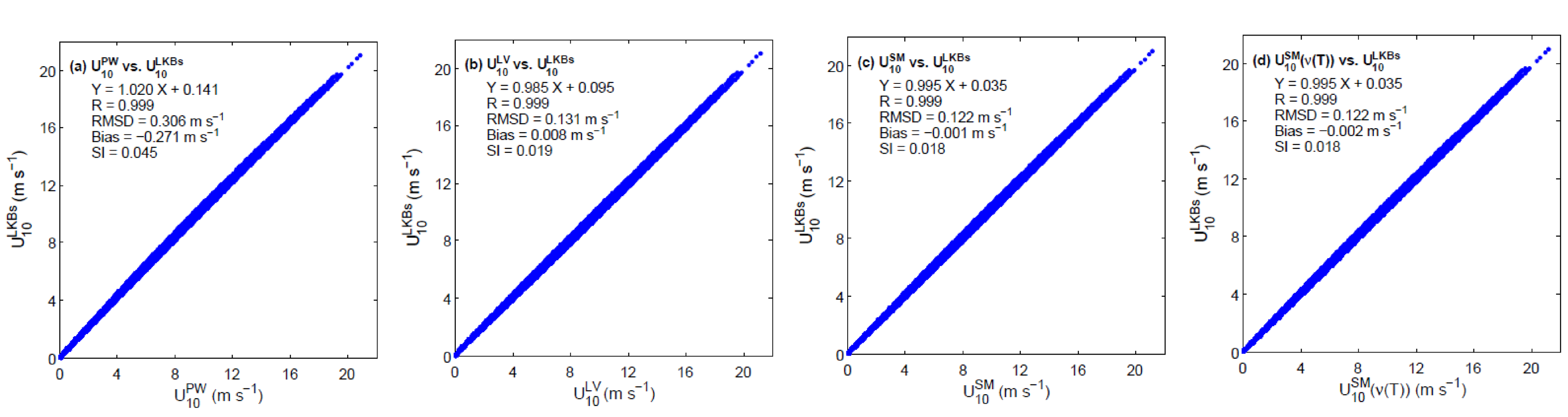


Figure 3. Comparisons between converted 10-m wind speed values from U_{10}^{LKBs} and converted values from each different formula, using 1-hr interval wind records observed at the Roof Deck on the Ieodo Ocean Research Station in 2015.

- Wind speed data adjusted from U_{10}^{SM} is the most similar to those of U_{10}^{LKBs}, showing the smallest values of RMSD, Bias and SI (Scatter Index), along with slope close to 1.
- Result of U_{10}^{SM}(ν(T)) is very closed to that of U_{10}^{SM}, revealing that effect of variable v is insignificant.
- U_{10}^{PW} tends to slightly overestimate whereas U_{10}^{LV} and U_{10}^{SM} tend to slightly underestimate.

Comparisons between ASCAT and adjusted wind data sets

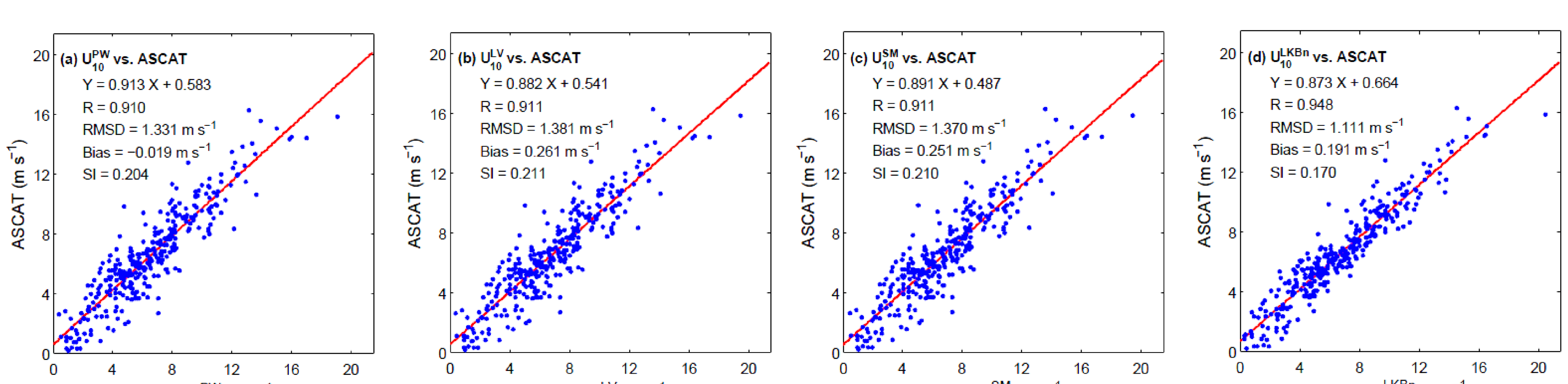


Figure 4. Comparisons between U_{10}^{ASCAT} and converted wind speed values from each different formula, using 1-hr interval wind records observed at the Roof Deck on the Ieodo Ocean Research Station in 2015.

- Wind speed data adjusted from U_{10}^{LKBn} is the most similar to those of ASCAT, showing the smallest values of RMSD, Bias and SI (Scatter Index), along with *R* value the nearest 1.
- For slope of linear regression, U_{10}^{PW} was closest to 1 following U_{10}^{SM}, U_{10}^{LV} and U_{10}^{LKBn}.
- Only U_{10}^{PW} has negative bias whereas the others have positive one.
- Interestingly, U_{10}^{PW} showed the second best performance, following by U_{10}^{SM} and U_{10}^{LV}.

Estimation of surface roughness length (z_o) around Ieodo ORS

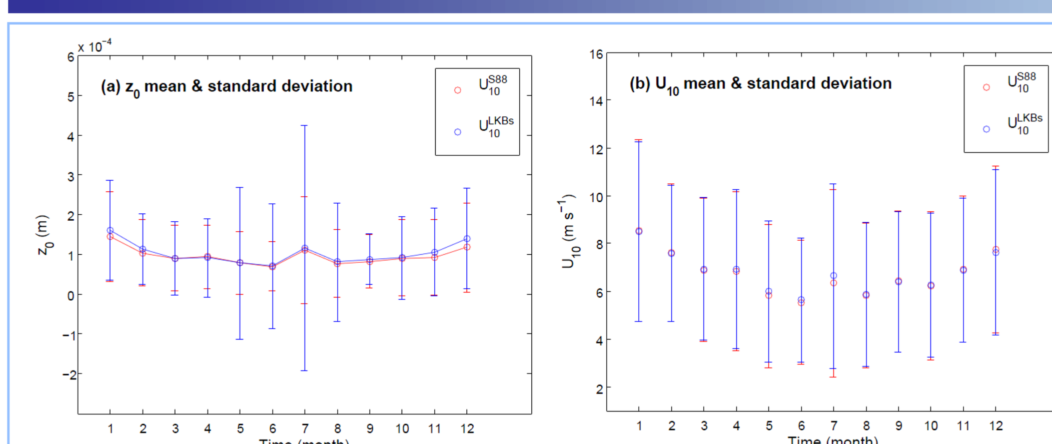


Figure 4. Monthly variabilities in mean and standard deviation of (a) surface roughness lengths (z_0) at the Ieodo Ocean Research Station and of (b) the wind speeds adjusted at 10-m, which were estimated from U_{10}^{SM} and U_{10}^{LKBs}.

- WMO (2008): 2×10^{-4} m for open sea
- Oh et al. (2014): 5×10^{-4} m for Ieodo area

- Monthly mean surface roughness lengths from both U_{10}^{SM} and U_{10}^{LKBs} were ranged from 0.69×10^{-4} m to 1.6×10^{-4} m, showing that U_{10}^{LKBs} has relatively higher monthly variation in z_0, compared to U_{10}^{SM}.
- 1-yr mean value of z_0 for each case is 0.96×10^{-4} m for U_{10}^{SM} and 10.2×10^{-5} m for U_{10}^{LKBs}, respectively.
- Wind speed adjusted from U_{10}^{LKBs} tends to be slightly smaller than that of U_{10}^{SM}.

Summary

- In terms of performance, U_{10}^{LKBs} is the best way to adjust wind speed at the Ieodo Ocean Research Station to a 10-m reference height but it requires several additional input data (air-temperature, air-pressure, relative humidity and sea-surface temperature).
- For real-time operational use, we suggest that U_{10}^{SM} showing the second best performance should be used in a complementary way of U_{10}^{LKBs}.
- The value of z_0 calculated from U_{10}^{LKBs} and U_{10}^{SM} using the Ieodo ORS observation records can be used in a simple conventional wind-speed conversion formula on the Ieodo area:

$$U_{10} = U_z \frac{ln\left(\frac{10}{z_0}\right)}{ln\left(\frac{z}{z_0}\right)}$$, $z_0 = 1.02\times10^{-4}$ m around the Ieodo ORS

References

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