

Estimation of Site Surface Roughness Length for Korean NPP Sites

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2019 IMUG Meeting

US NRC Headquarters, North Bethesda, MD

June 10-11, 2019

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Land Cover and Surface Roughness

- Application of Local Topographic Characteristics when Performing Level 3 PSA -

Various Types of Land Cover



- **Surface roughness:** Express characteristics of land cover and land use
 - Mathematical expression: **Surface roughness length** or **aerodynamic roughness length**
 - Mathematical definition: Height where wind speed prediction becomes zero by frictional drag close to the ground

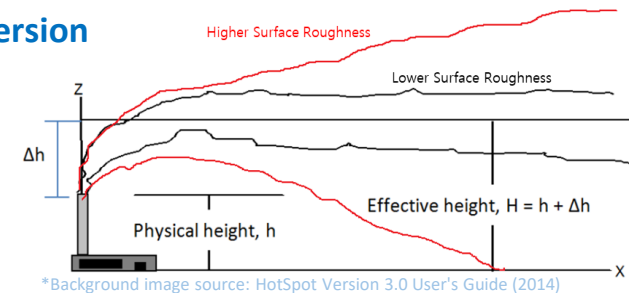
Influence of Surface Roughness

■ Influence on both Dispersion and Deposition

• Atmospheric Dispersion

- **Rougher surface** make more turbulence → **Higher vertical dispersion**
- Influence on vertical dispersion factor (σ_z)

$$\sigma_z = \sigma_{z,PG} \left(\frac{z_0}{3} \right)^{0.2}$$



• Ground Deposition

- **Rougher surface** make more friction and shear stress → **Higher ground deposition**
- Influence on dry deposition velocity (v_d)

$$\ln(v_d) = -2.964 + 0.992(\ln d_p) + 0.190(\ln d_p)^2 - 0.072(\ln d_p)^3 + 1.061z_0 + 0.169V$$

■ Surface Roughness is Input as **One Representative Value**

- Code using Gaussian plume model: MACCS, HotSpot
- *In the U.S., the Department of Energy recommends basing the value used for surface roughness on “a macroscopic average for the region-of-transport and should be consistent for the environment surrounding facility in question.” (2017.12.06. Q&A with Dr. Nathan Bixler)*
- **Estimating appropriate representative value is important**

Application of Surface Roughness

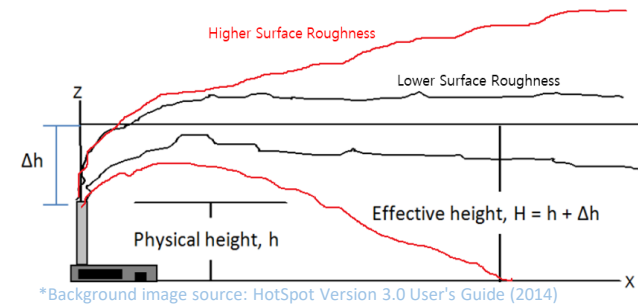
■ US

- Used generic value (10 cm) for a long time
 - Siting Study (NUREG/CR-2239, 1982)
 - Severe Accident Risk (NUREG-1150, 1990)
 - Most other previous studies

- US SOARCA (Peach Bottom): Sensitivity Analysis

- $z_0 = 10 \text{ cm}$ (corn field) → 60 cm (forest)
 - › 10% LCF risk increase within 10 miles
 - › 20% LCF risk reduction for the intermediate distances (10 to 50 miles)

- US SOARCA (Sequoyah): Apply representative surface roughness ($z_0 = 39 \text{ cm}$)
 - Area-weighted average within 30 miles radius
 - By using CropScape

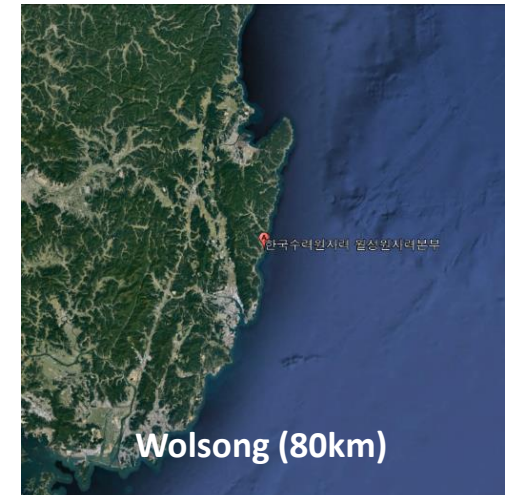


■ Korea

- Necessity has been recognized for a long time
- Absence of method and tool → Used default value (10 cm)

Land Cover of US and Korean NPP Sites

- Korean Site has **Complex Terrain** Relatively



Development of Method and Software to Calculate Site Surface Roughness Length in Korea

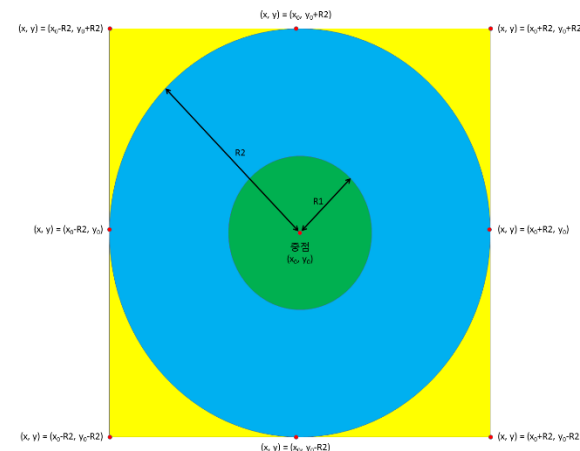
Method to Estimate Representative Roughness Length (z_0)

■ Raw Data of Land Cover

- Entire area of South Korea
- Resolution: 30m × 30m
- Land Cover Code
 - 1. Water
 - 2. Urban
 - 3. Bare Land
 - 4. Waterland
 - 5. Grassland
 - 6. Forest
 - 7. Rice Field
 - 8. Other Field

■ Method

1. Assign z_0 to each land cover code
2. Set area to make average



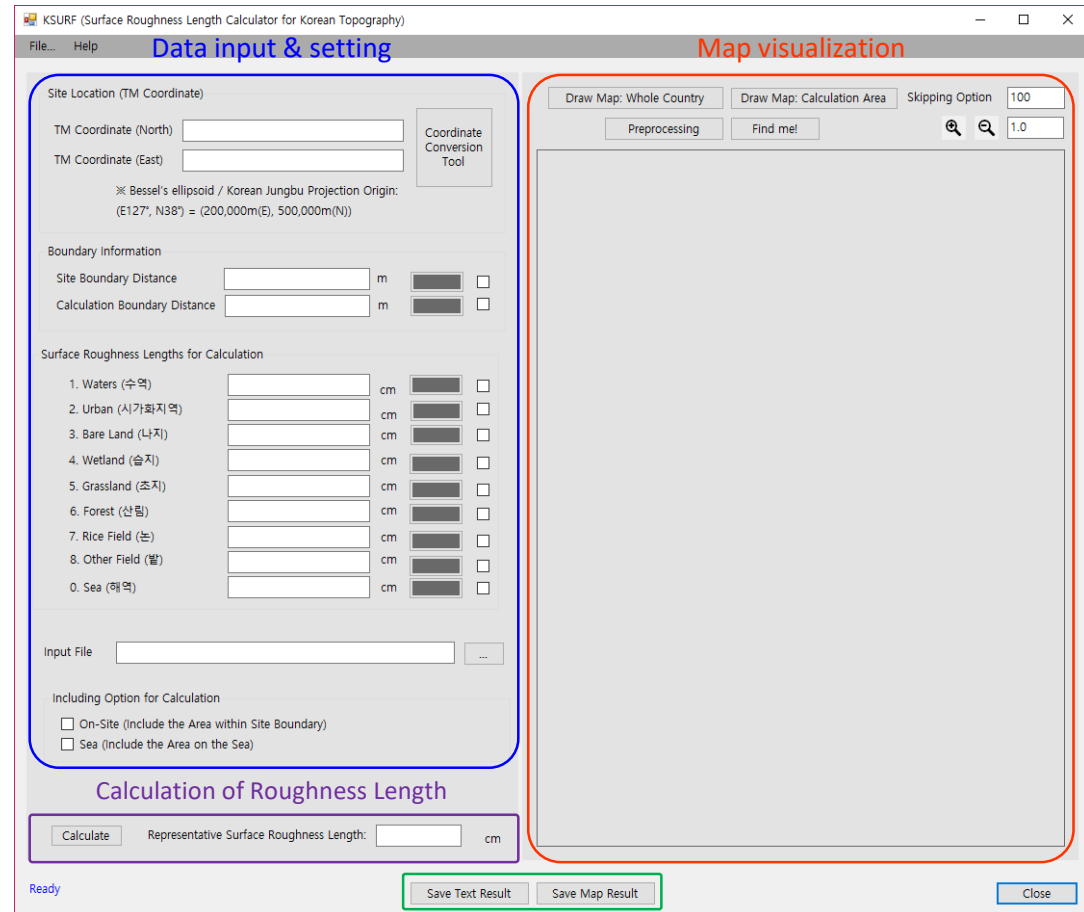
3. Extract data from set area
4. Area-weighted average of z_0

$$\frac{\sum_i (z_{0,i} \times a_i)}{\sum_i a_i}$$

Development of Software

■ Development & Execution Environment

- Coding language
 - C# and C++
 - .NET Framework 4.6
- Operating system
 - Microsoft Windows 7 or above
 - 64 bit
- Component
 - Data input & setting
 - Calculation of Roughness Length
 - Map visualization
 - Saving text & image result (including simple statistics)



Saving text & image result

■ Set Site Location

- Coordinate Conversion Tool
 - TM coordinate
 - Bessel ellipsoid
 - Korean Jungbu projection origin

Coordinate Conversion

Input Latitude and Longitude in DMS or Degree Format and Click Convert Button

DMS

D M S

Latitude (위도)

Longitude (경도)

DMS <- Degree

Degree

Latitude (위도)

Longitude (경도)

DMS -> Degree

TM Coordinate

TM Coordinate (North)

TM Coordinate (East)

Convert

OK Cancel

KSURF (Surface Roughness Length Calculator for Korean Topography)

File... Help

Site Location (TM Coordinate)

TM Coordinate (North)

TM Coordinate (East)

※ Bessel's ellipsoid / Korean Jungbu Projection Origin:
(E127°, N38°) = (200,000m(E), 500,000m(N))

Coordinate Conversion Tool

Boundary Information

Site Boundary Distance m ☐

Calculation Boundary Distance m ☐

Surface Roughness Lengths for Calculation

<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>
<input type="text"/>	cm	<input type="checkbox"/>

Calculation

Area within Site Boundary

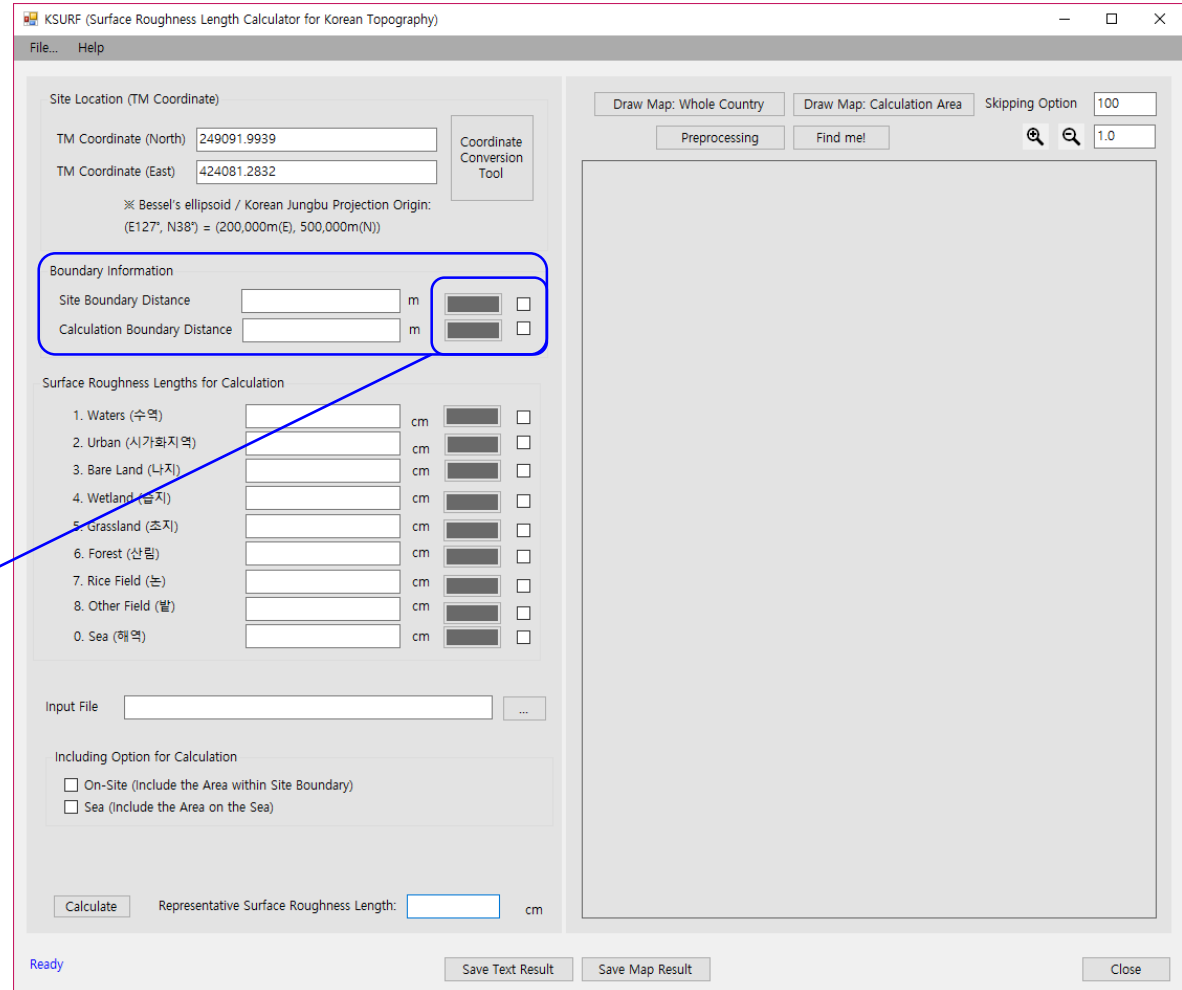
Area on the Sea

Representative Surface Roughness Length: cm

Save Text Result Save Map Result Close

■ Set Calculation Area

- Site boundary
- Calculation boundary
- Color Setting & Checkbox



Assign Roughness Length

- Assign corresponding z_0 to each land cover
- Color Setting & Checkbox

Import Raw Data

Set Area Inclusion

- On-site area
- Sea area

KSURF (Surface Roughness Length Calculator for Korean Topography)

File... Help

Site Location (TM Coordinate)

TM Coordinate (North) 249091.9939

TM Coordinate (East) 424081.2832

Coordinate Conversion Tool

※ Bessel's ellipsoid / Korean Jungbu Projection Origin: (E127°, N38°) = (200,000m(E), 500,000m(N))

Boundary Information

Site Boundary Distance 914 m

Calculation Boundary Distance 8000 m

Surface Roughness Lengths for Calculation

No.	Land Cover	Length	Unit	Color	Checkbox
1.	Waters (수역)	0.1	cm	Cyan	<input checked="" type="checkbox"/>
2.	Urban (시가화지역)	100	cm	Purple	<input checked="" type="checkbox"/>
3.	Bare Land (나지)	1	cm	Yellow	<input checked="" type="checkbox"/>
4.	Wetland (습지)	5	cm	Green	<input checked="" type="checkbox"/>
5.	Grassland (초지)	3	cm	Light Green	<input checked="" type="checkbox"/>
6.	Forest (산림)	100	cm	Dark Green	<input checked="" type="checkbox"/>
7.	Rice Field (논)	10	cm	Gold	<input checked="" type="checkbox"/>
8.	Other Field (밭)	5	cm	Bright Green	<input checked="" type="checkbox"/>
0.	Sea (해역)	0.1	cm	Blue	<input checked="" type="checkbox"/>

Input File E:\KSURF\RAWData\LAND.txt

Including Option for Calculation

☐ On-Site (include the Area within Site Boundary)

☐ Sea (include the Area on the Sea)

Calculate Representative Surface Roughness Length: cm

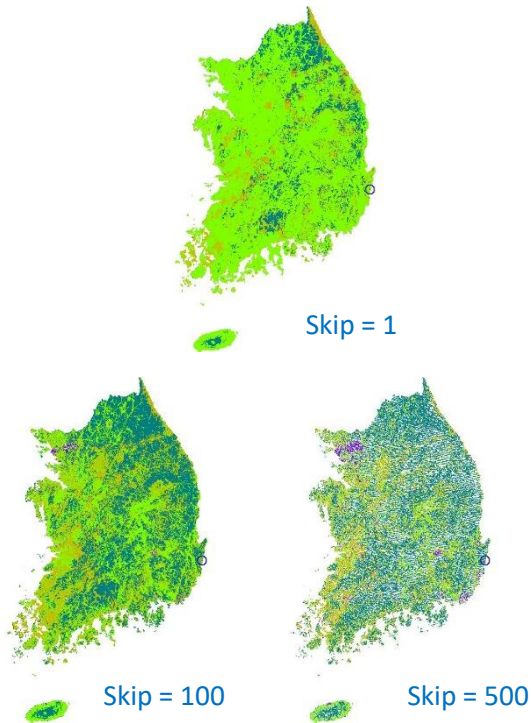
Ready

Save Text Result Save Map Result Close

■ Visualization

- Color overlaying problem due to high resolution (30m × 30m) of raw data

→ Skipping option



KSURF (Surface Roughness Length Calculator for Korean Topography)

File... Help

Site Location (TM Coordinate)

TM Coordinate (North) 249091.9939

TM Coordinate (East) 424081.2832

Coordinate Conversion Tool

※ Bessel's ellipsoid / Korean Jungbu Projection Origin: (E127°, N38°) = (200,000m(E), 500,000m(N))

Boundary Information

Site Boundary Distance 914 m

Calculation Boundary Distance 8000 m

Surface Roughness Lengths for Calculation

No.	Category	Value	Unit	Color	Check
1.	Waters (수역)	0.1	cm	Cyan	<input checked="" type="checkbox"/>
2.	Urban (시가화지역)	100	cm	Purple	<input checked="" type="checkbox"/>
3.	Bare Land (나지)	1	cm	Yellow	<input checked="" type="checkbox"/>
4.	Wetland (습지)	5	cm	Green	<input checked="" type="checkbox"/>
5.	Grassland (초지)	3	cm	Light Green	<input checked="" type="checkbox"/>
6.	Forest (산림)	100	cm	Dark Green	<input checked="" type="checkbox"/>
7.	Rice Field (논)	10	cm	Gold	<input checked="" type="checkbox"/>
8.	Other Field (밭)	5	cm	Bright Green	<input checked="" type="checkbox"/>
0.	Sea (해역)	0.1	cm	Blue	<input checked="" type="checkbox"/>

Input File E:\KSURF\RAWData\LAND.txt

Including Option for Calculation

☒ On-Site (Include the Area within Site Boundary)

☐ Sea (Include the Area on the Sea)

Calculate Representative Surface Roughness Length: cm

Processed 106,914,040 lines.

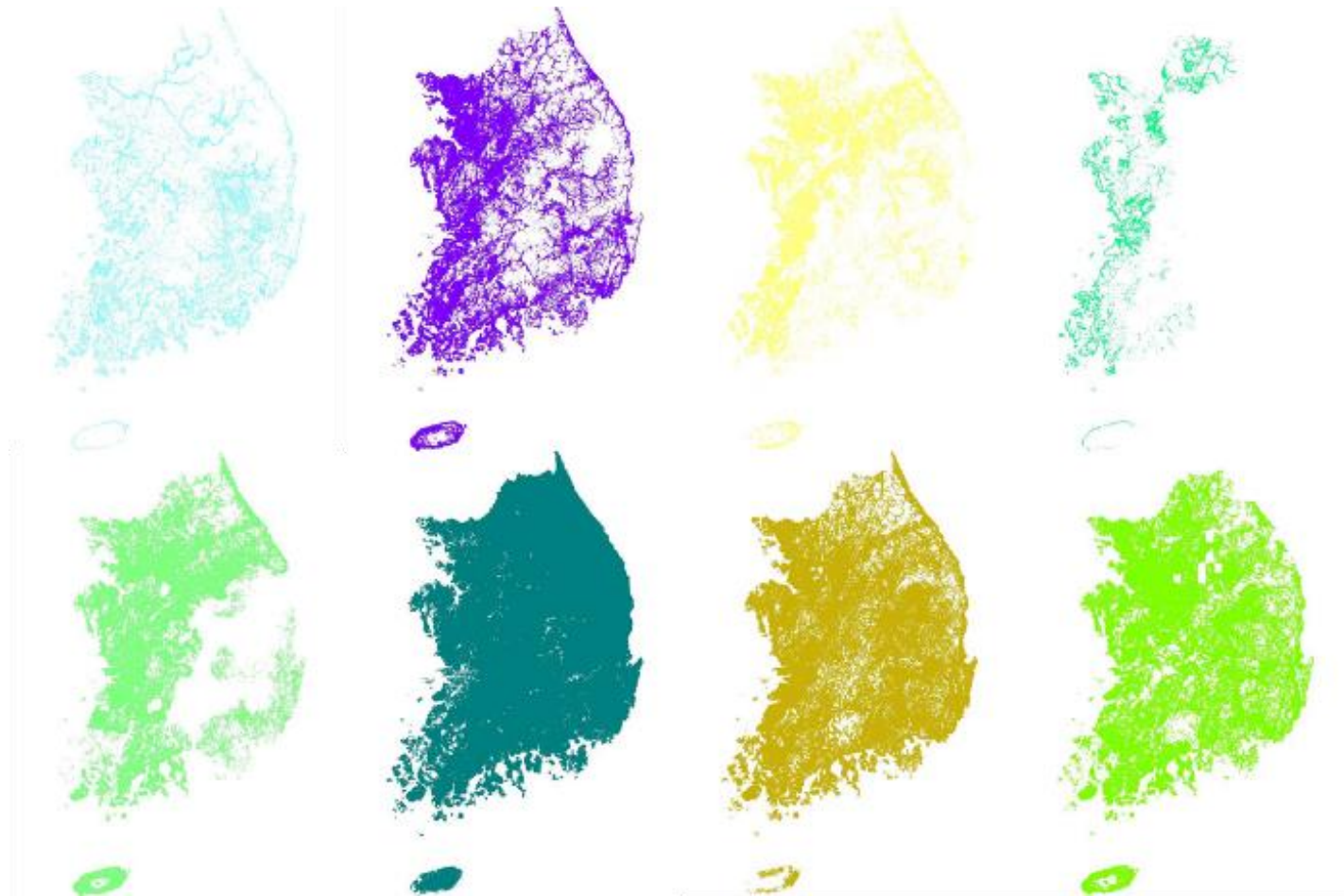
Save Text Result Save Map Result Close

Draw Map: Whole Country Draw Map: Calculation Area Skipping Option 100

Preprocessing Find me!

1.0

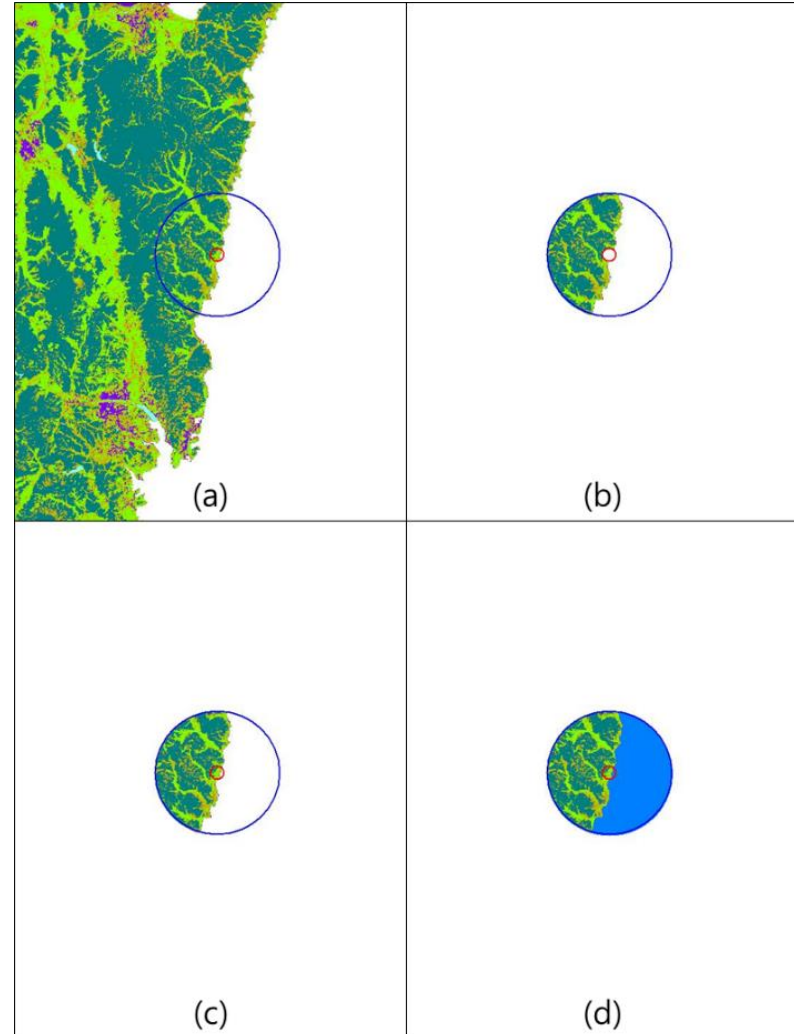
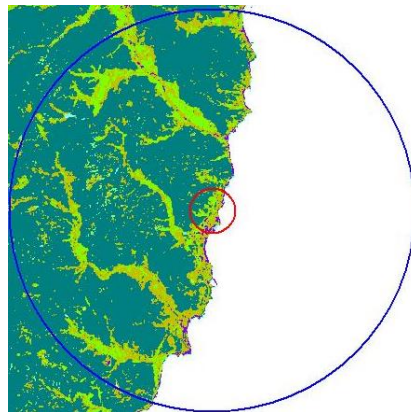
- Visualization Results
 - Visualization of each land cover (Skipping option = 1)



■ Visualization Option

- Draw Map: Whole Country
- Draw Map: Calculation Area – Excluding On-Site Area
- Draw Map: Calculation Area – Including On-Site Area
- Draw Map: Calculation Area – Including On-Site & Sea Area

※ Option of “Draw Map: Calculation Area” facilitate verification



Print Text Output

Calculated by KSURF Version 1.0.14

User Input

Location (Center Point)
-TM Coordinate: N249091.9939 E424081.2832

Site Boundary Distance (m): 910

Calculation Boundary Distance (m): 8000

Surface Roughness Lengths Used for the Calculation

- Waters (수역): 0.1 cm
- Urban (시가합치역): 100 cm
- Bare Land (나지): 1 cm
- Wetland (습지): 5 cm
- Grassland (초지): 3 cm
- Forest (산림): 100 cm
- Rice Field (논): 10 cm
- Other Field (밭): 5 cm
- Sea (해역): 0.1 cm

Including Option for the Calculation

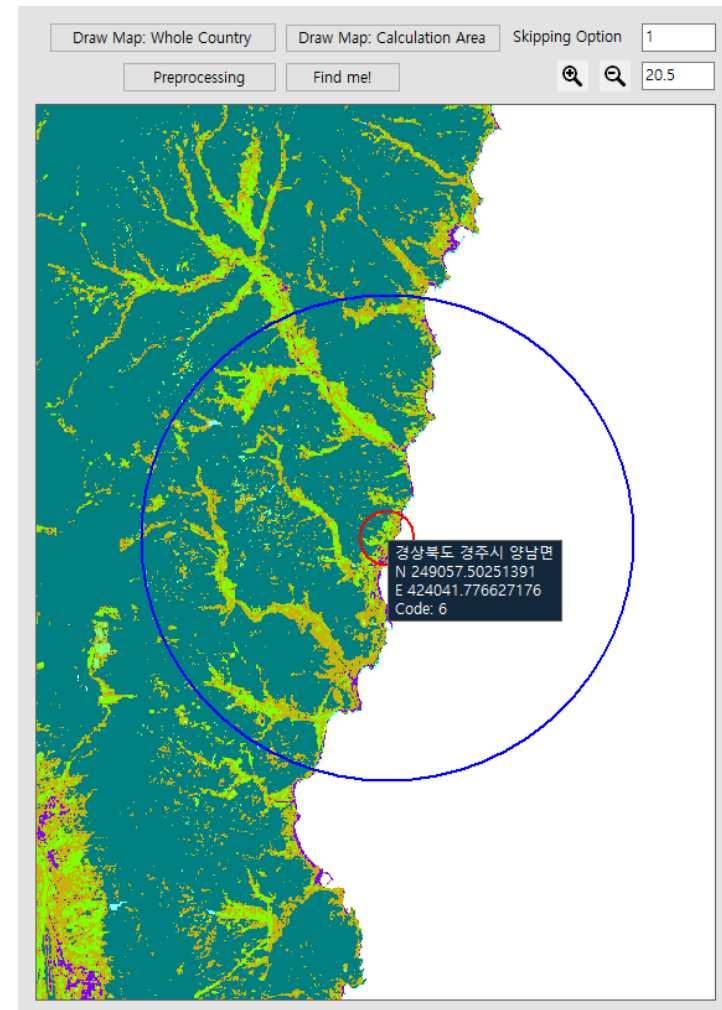
- On-Site (Include the Area within Site Boundary): O
- Sea (Include the Area on the Sea): X

Input File: E:\KSRUF\RAWData\LAND.txt

Results

Roughness	Length	Count	Fraction
- Waters (수역):	0.1 cm	423	0.0037
- Urban (시가합치역):	100 cm	1317	0.0115
- Bare Land (나지):	1 cm	26	0.0002
- Wetland (습지):	5 cm	0	0.0000
- Grassland (초지):	3 cm	1325	0.0116
- Forest (산림):	100 cm	85727	0.7510
- Rice Field (논):	10 cm	18173	0.1592
- Other Field (밭):	5 cm	7161	0.0627
- Sea (해역):	0.1 cm	0	0.0000

Print Image Output



Estimation of Site Roughness Length for Korean NPP Sites

Assigning Typical Roughness Length

Code	Land Use	Before	Now	SNL (RAPS, 1987)	Stull (1988)	Visscher (2014)
1	Waters	0.03	0.1	0.03 (open water)		0.001-0.01 (water, snow) 0.1 (CALPUFF default)
2	Urban	100	100	70 (developed/medium intensity) 350 (developed/high intensity)	60 (centers of small town) 100 (centers of large towns and cities) 120-250 (centers of cities with very tall BD)	50-100 (suburbs) 200-400 (city centers) 100 (CALPUFF default)
3	Bare Land	1	1	1 (barren)		
4	Waterland	5	5	5 (waterlands)		25 (irrigated)
5	Grassland	3	3	3 (grass/pasture)	1.8 (uncut grass) 0.6 (cut grass (=3 cm))	1 (lawn) 0.5-3 (prairie) 0.5-1 (cut grass)
6	Forest	60	100	60 (forest)	80 (forest)	50-100 (lower when the canopy is very dense (skimming flow)) 100 (CALPUFF default)
	Mountain				100 (low mtns) 120-250 (very highly or moderated mountainous area) 600 (100-150m E. Tenn. Mt.) 3000 (180m W. Virginia Mt.) 5000-7000 (Rocky Mt.)	500-7000 (Rocky Mt.: 5000-7000)
7	Rice Field	10	10	10 (farmland)	0.7-2 (rice) 2-10 (farmland)	3-10 (farmland)
8	Other Field	5	5	5 (shrub land)	3-10 (farmland)	3-10 (farmland)
0	Sea	0.03	0.1		0.09 (off-sea wind in coastal area) 0.01 (calm open sea)	0.01-0.1 (open sea)

Land Cover Fraction of Korean NPP Sites

■ ShinKori Site

- 8 km boundary (z_0 for dispersion)

ShinKori Site within 8 km		
Land Cover	Count	Fraction
Water	606	0.58%
Urban	2,397	2.29%
Bare Land	46	0.04%
Waterland	0	0.00%
Grassland	1,427	1.36%
Forest	69,565	66.41%
Rice Field	24,787	23.66%
Other Field	5,927	5.66%
Sea	0	0.00%

- 80 km boundary (z_0 for deposition)

ShinKori Site within 80 km		
Land Cover	Count	Fraction
Water	115,481	1.28%
Urban	421,045	4.65%
Bare Land	21,358	0.24%
Waterland	0	0.00%
Grassland	36,489	0.40%
Forest	5,958,040	65.87%
Rice Field	1,593,361	17.61%
Other Field	900,061	9.95%
Sea	0	0.00%

■ Wolsong Site

- 8 km boundary (z_0 for dispersion)

Wolsong Site within 8 km		
Land Cover	Count	Fraction
Water	423	0.37%
Urban	1,317	1.15%
Bare Land	26	0.02%
Waterland	0	0.00%
Grassland	1,325	1.16%
Forest	85,727	75.10%
Rice Field	18,173	15.92%
Other Field	7,161	6.27%
Sea	0	0.00%

- 80 km boundary (z_0 for deposition)

Wolsong Site within 80 km		
Land Cover	Count	Fraction
Water	102,495	1.06%
Urban	355,209	3.69%
Bare Land	18,529	0.19%
Waterland	0	0.00%
Grassland	28,934	0.30%
Forest	6,710,171	69.65%
Rice Field	1,507,708	15.65%
Other Field	911,316	9.46%
Sea	0	0.00%

Calculation of Roughness Length (z_0), Vertical Dispersion Parameter (σ_z) and Dry Deposition Velocity (v_d)

■ Default

- $Z_0 = 10$ cm

Land Cover	Length (cm)	8 km	80 km
Water	10 (Default)	10	10
Urban		σ_z	v_d (m/s)
Bare Land		1.27	BIN1 4.15E-04
Waterland			BIN2 4.62E-04
Grassland			BIN3 6.92E-04
Forest			BIN4 1.26E-03
Rice Field			BIN5 2.53E-03
Other Field			BIN6 5.06E-03
Sea			BIN7 9.13E-03
			BIN8 1.34E-02
			BIN9 2.52E-02
			BIN10 8.56E-02
			BIN11 2.91E-01
			BIN12 9.94E-01

■ Base Case

- Calculate Z_0 assigning roughness length of forest as 100 cm

Land Cover	Length (cm)	8 km	80 km
Water	0.10	71	73
Urban	100	σ_z	v_d (m/s)
Bare Land	1	1.88	BIN1 8.10E-04
Waterland	5		BIN2 9.01E-04
Grassland	3		BIN3 1.35E-03
Forest	100		BIN4 2.46E-03
Rice Field	10		BIN5 4.94E-03
Other Field	5		BIN6 9.87E-03
Sea	0.10		BIN7 1.78E-02
			BIN8 2.62E-02
			BIN9 2.52E-02
			BIN10 8.56E-02
			BIN11 2.91E-01
			BIN12 9.94E-01

■ Sensitivity Case

- Calculate Z_0 assigning roughness length of forest as 500 cm

Land Cover	Length (cm)	8 km	80 km
Water	0.10	337	336
Urban	100	σ_z	v_d (m/s)
Bare Land	1	2.57	BIN1 1.32E-02
Waterland	5		BIN2 1.47E-02
Grassland	3		BIN3 2.20E-02
Forest	500		BIN4 4.01E-02
Rice Field	10		BIN5 8.04E-02
Other Field	5		BIN6 1.61E-01
Sea	0.10		BIN7 2.90E-01
			BIN8 4.27E-01
			BIN9 2.52E-02
			BIN10 8.56E-02
			BIN11 2.91E-01
			BIN12 9.94E-01

Summary and Conclusion

Summary and Conclusion

- **Need** to apply representative surface roughness for complex terrain of Korean NPP sites
 - No existing method & tool in Korea
- **Method** to calculate site surface roughness
 - Not rough guess but mathematical approach
- **Tool** to accept various way of calculation flexibly
 - Possible to include/exclude on-site and sea area in calculation



Realization of Applying Korean Topography for Level 3 PSA

- It is expected that this tool can be used helpfully until when MACCS or other Level 3 PSA code employs specific roughness length for each spatial grid in the future.

Thank you.