

Estimation of Site Surface Roughness Length for Korean NPP Sites

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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

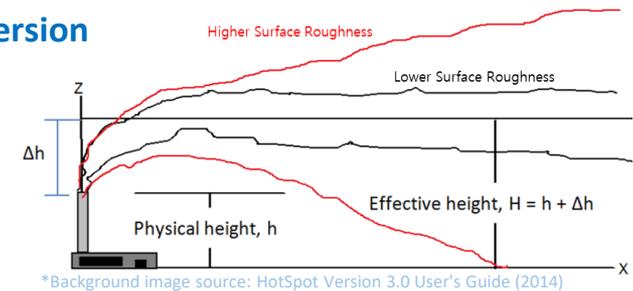
Influence of Surface Roughness

■ Influence on both Dispersion and Deposition

• Atmospheric Dispersion

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

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



*Background image source: HotSpot Version 3.0 User's Guide (2014)

• 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

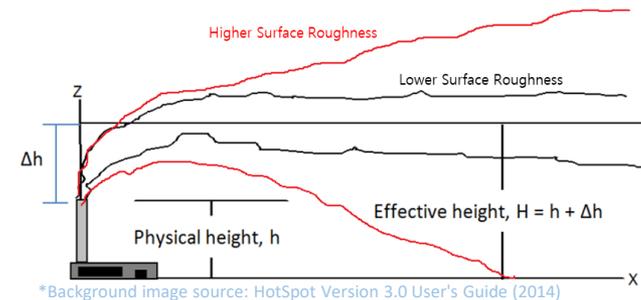
- $z_0 = 10 \text{ cm}$ (corn field) → **60 cm** (forest)
 - › 10% LCF **risk increase within 10 miles**
 - › 20% LCF **risk reduction** for the **intermediate distances** (10 to 50 miles)

- US SOARCA (Sequoyah): Apply representative surface roughness ($z_0 = 39 \text{ cm}$)

- Area-weighted average within 30 miles radius
- By using CropScape

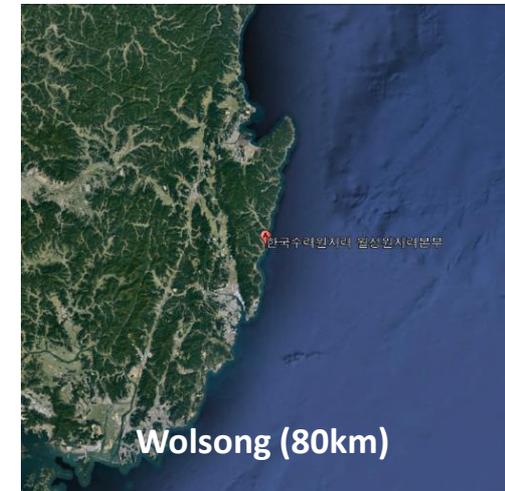
■ Korea

- 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

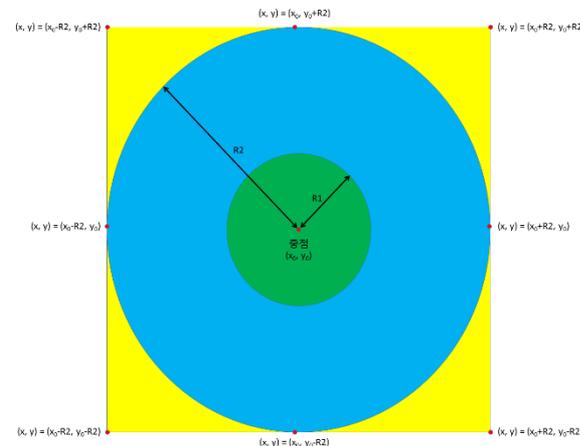
Method to Estimate Representative Roughness Length (z_0)

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



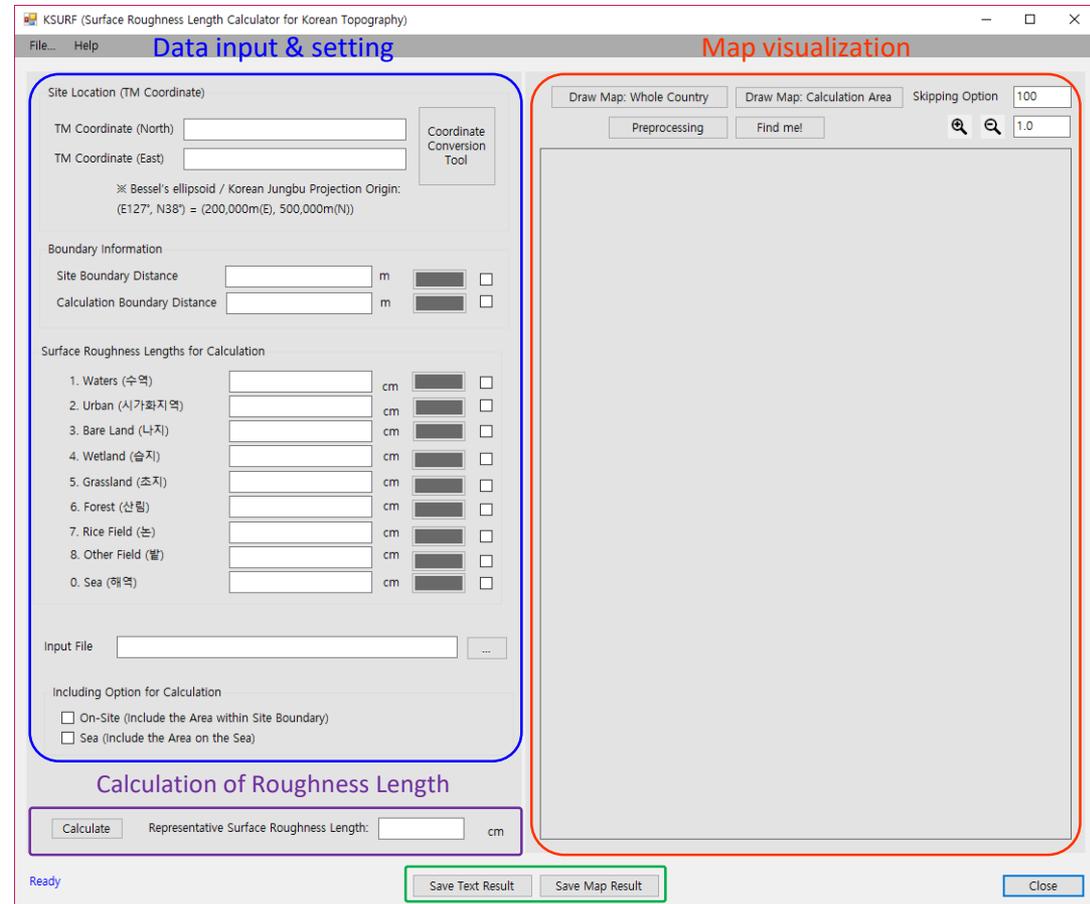
3. Extract data from set area
4. Area-weighted average of z_0

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

Development of Software

■ Development & Execution Environment

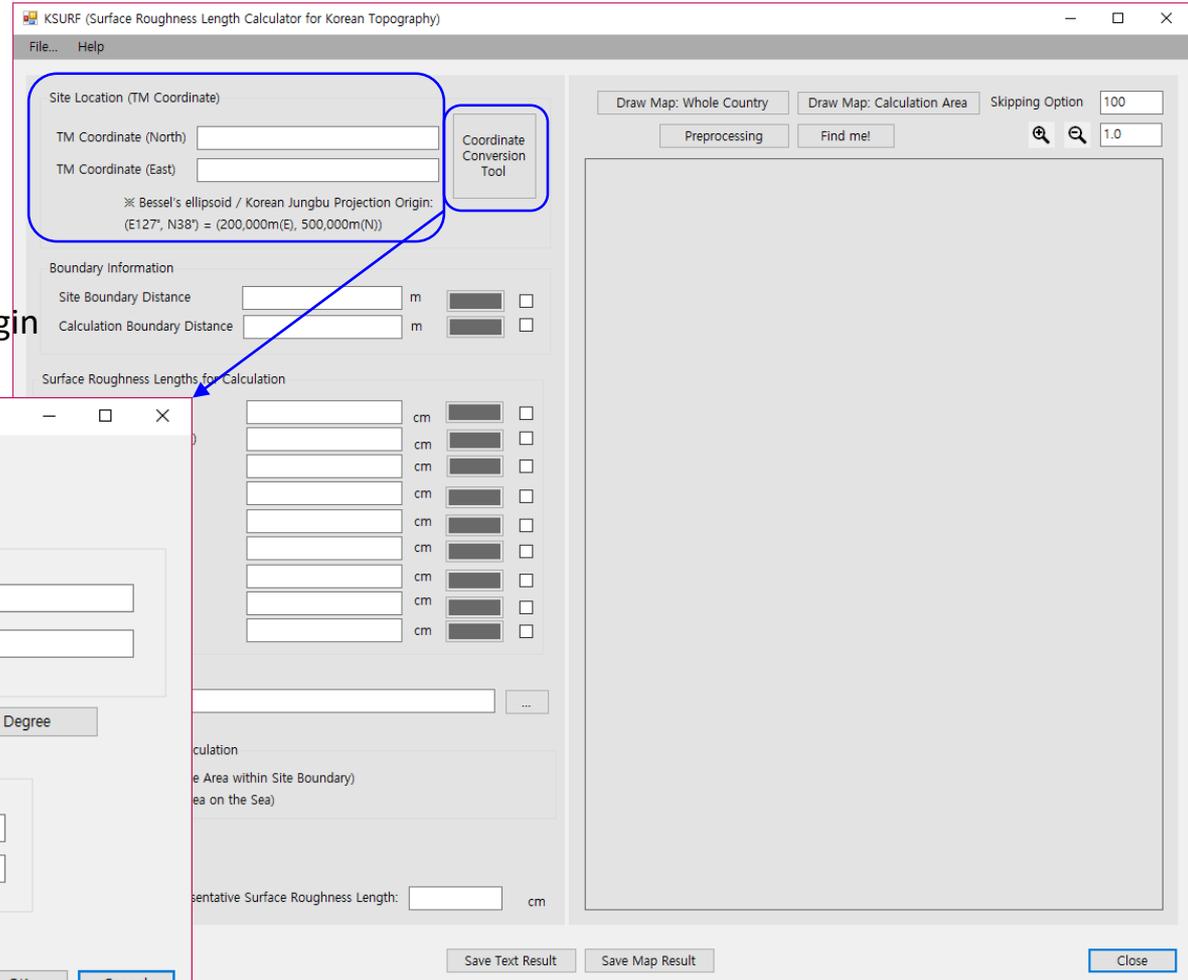
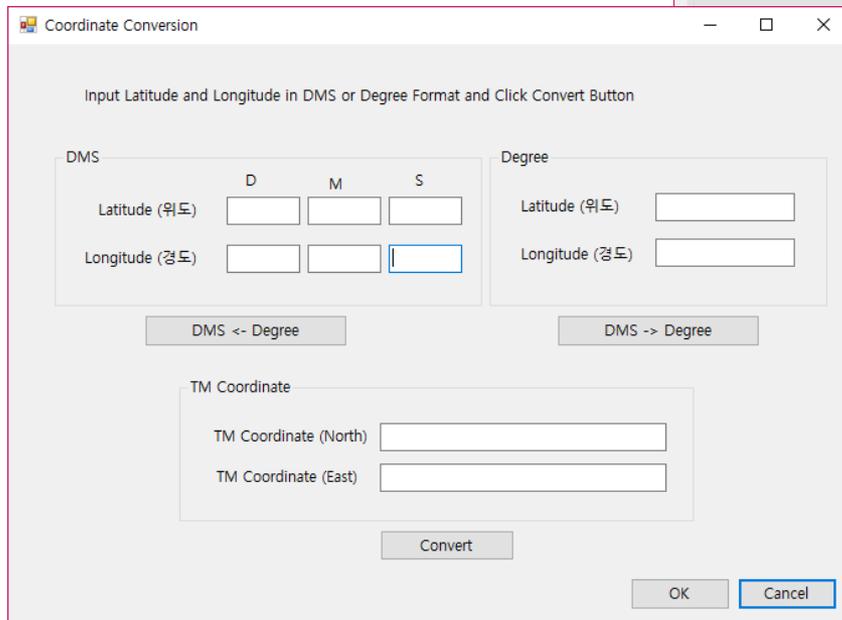
- Coding language
 - C# and C++
 - .NET Framework 4.6
- Operating system
 - Microsoft Windows 7 or above
 - 64 bit
- Component
 - Data input & setting
 - Calculation of Roughness Length
 - Map visualization
 - Saving text & image result (including simple statistics)



Saving text & image result

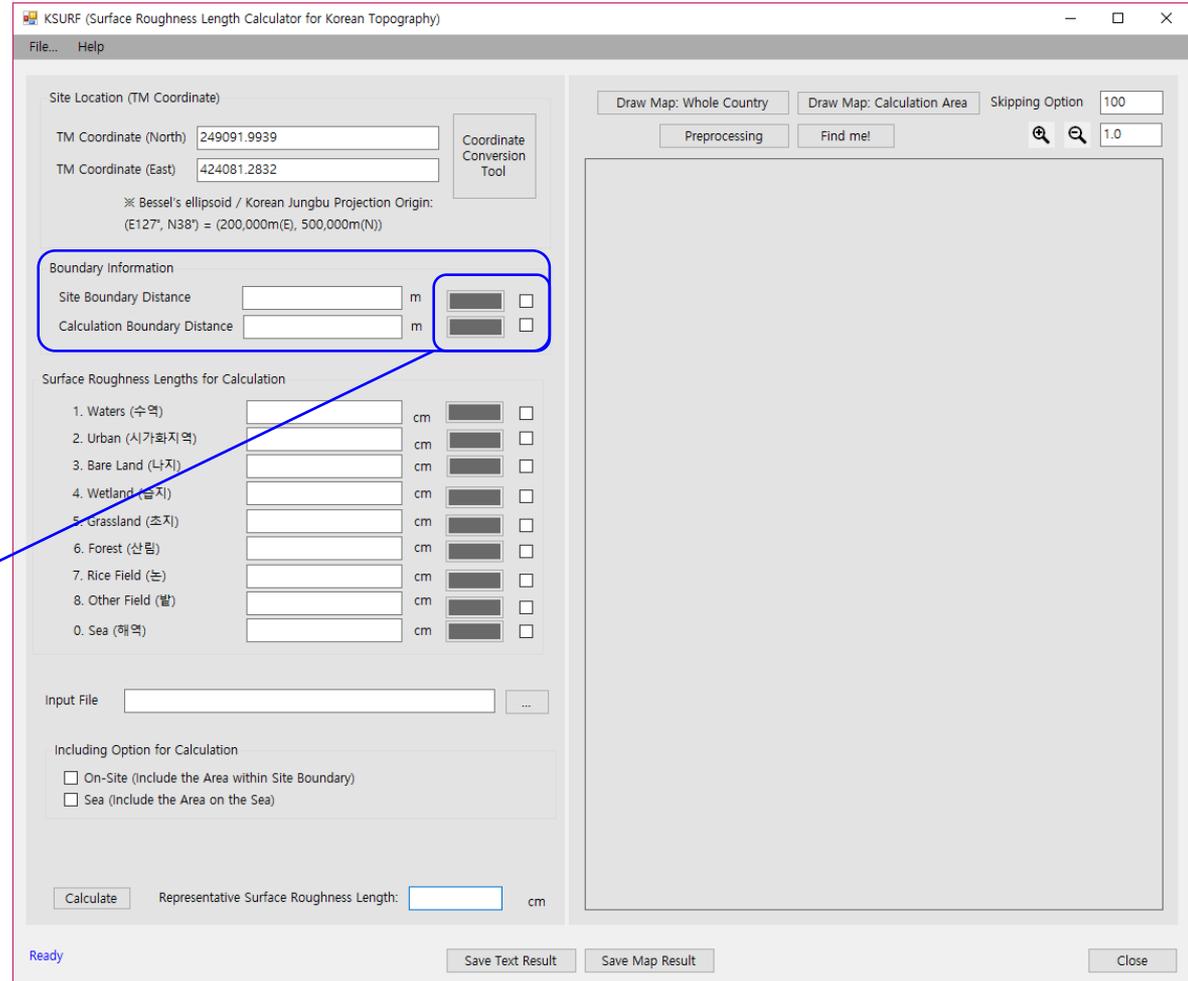
■ Set Site Location

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



■ 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 (Korean)	Roughness Length (cm)	Color	Checkbox
1.	Waters (수역)	0.1	Cyan	<input checked="" type="checkbox"/>
2.	Urban (시가화지역)	100	Purple	<input checked="" type="checkbox"/>
3.	Bare Land (나지)	1	Yellow	<input checked="" type="checkbox"/>
4.	Wetland (습지)	5	Green	<input checked="" type="checkbox"/>
5.	Grassland (초지)	3	Light Green	<input checked="" type="checkbox"/>
6.	Forest (산림)	100	Dark Green	<input checked="" type="checkbox"/>
7.	Rice Field (논)	10	Olive Green	<input checked="" type="checkbox"/>
8.	Other Field (밭)	5	Light Green	<input checked="" type="checkbox"/>
0.	Sea (해역)	0.1	Blue	<input checked="" type="checkbox"/>

Input File E:\KSRUF\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

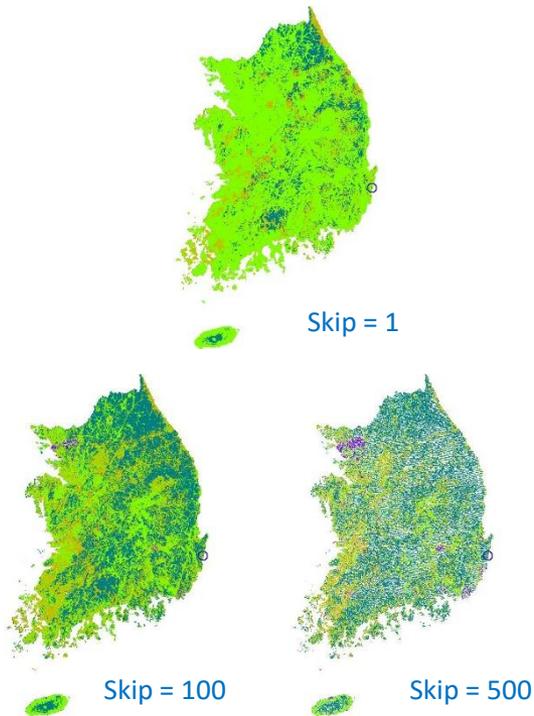
Ready

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) Coordinate Conversion Tool

TM Coordinate (East)

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

Boundary Information

Site Boundary Distance m

Calculation Boundary Distance m

Surface Roughness Lengths for Calculation

1. Waters (수역)	<input type="text" value="0.1"/>	cm	<input checked="" type="checkbox"/>
2. Urban (시가화지역)	<input type="text" value="100"/>	cm	<input checked="" type="checkbox"/>
3. Bare Land (나지)	<input type="text" value="1"/>	cm	<input checked="" type="checkbox"/>
4. Wetland (습지)	<input type="text" value="5"/>	cm	<input checked="" type="checkbox"/>
5. Grassland (초지)	<input type="text" value="3"/>	cm	<input checked="" type="checkbox"/>
6. Forest (산림)	<input type="text" value="100"/>	cm	<input checked="" type="checkbox"/>
7. Rice Field (논)	<input type="text" value="10"/>	cm	<input checked="" type="checkbox"/>
8. Other Field (밭)	<input type="text" value="5"/>	cm	<input checked="" type="checkbox"/>
0. Sea (해역)	<input type="text" value="0.1"/>	cm	<input checked="" type="checkbox"/>

Input File ...

Including Option for Calculation

On-Site (Include the Area within Site Boundary)

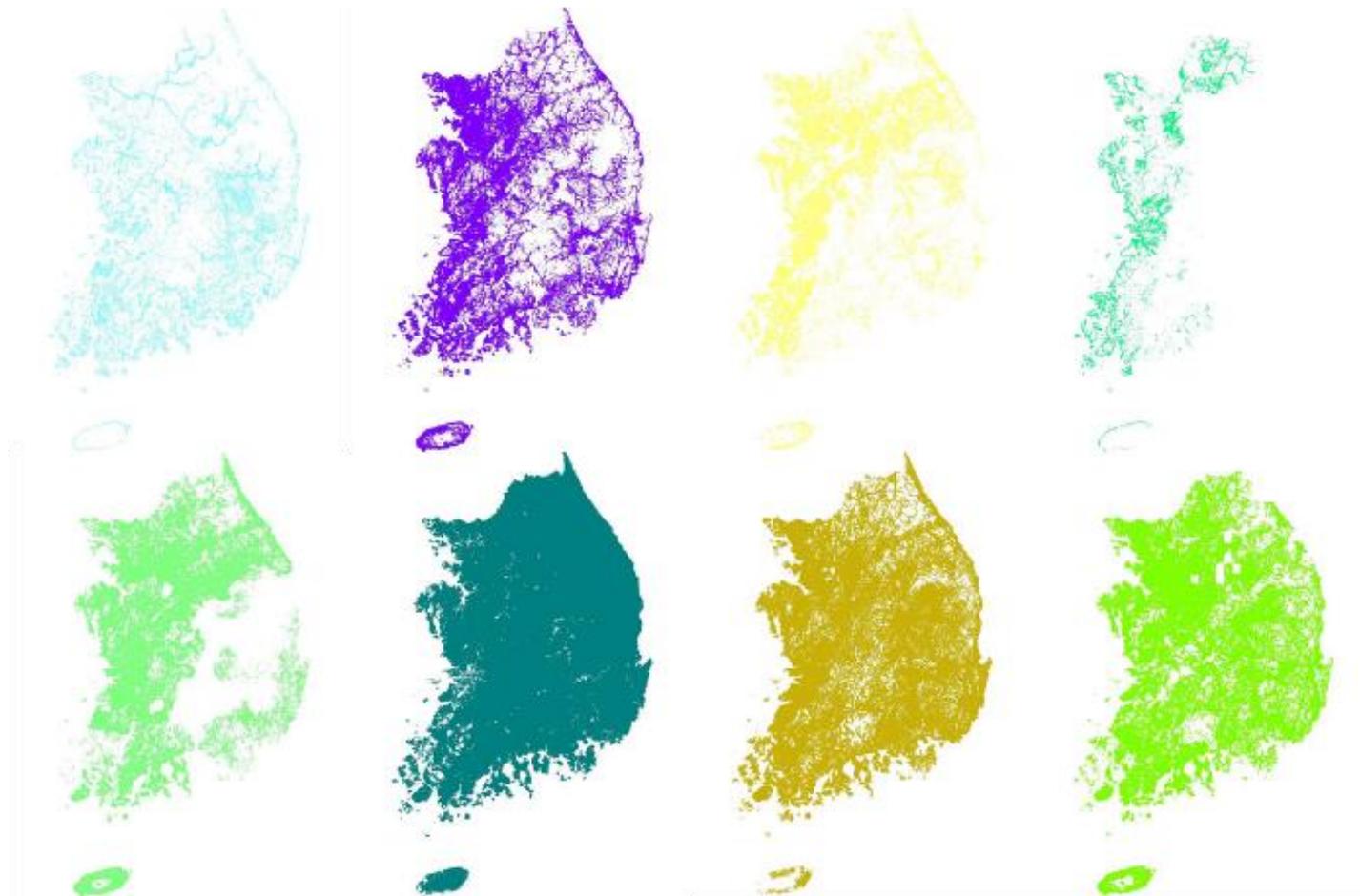
Sea (Include the Area on the Sea)

Representative Surface Roughness Length: cm

Processed 106,914,040 lines.

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

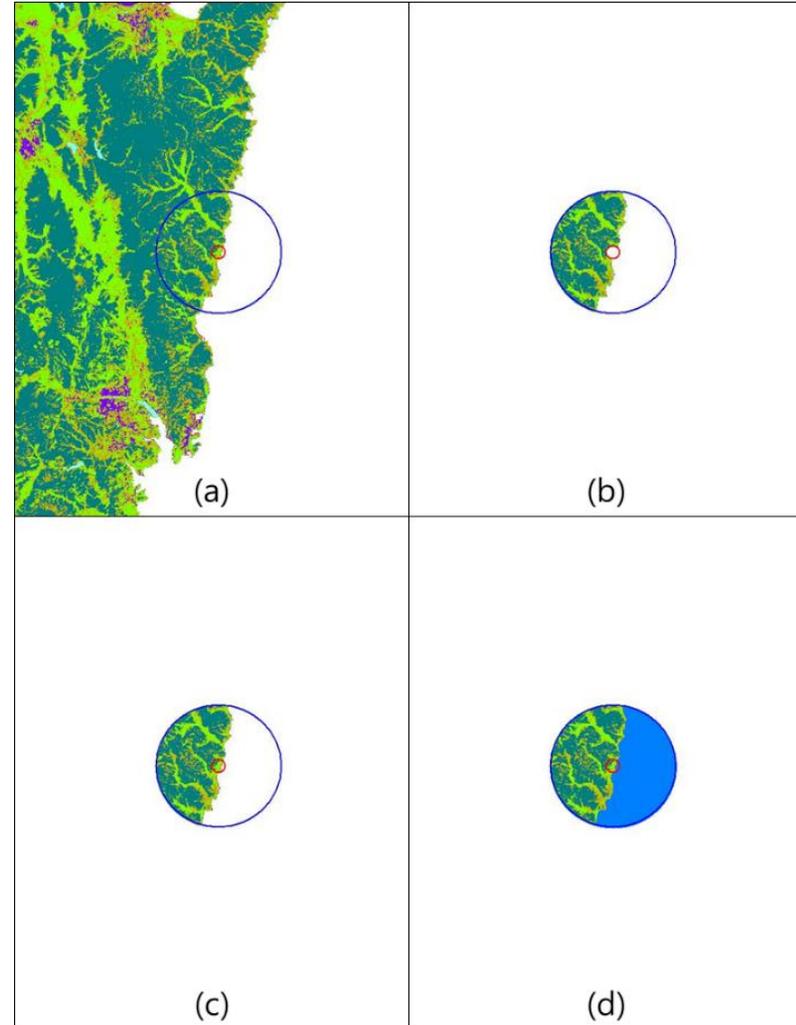
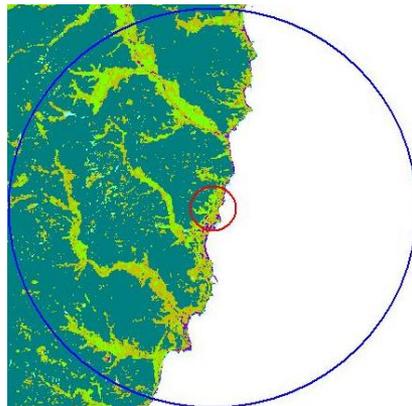
- Visualization Results
 - Visualization of each land cover (Skipping option = 1)



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



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		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	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	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.