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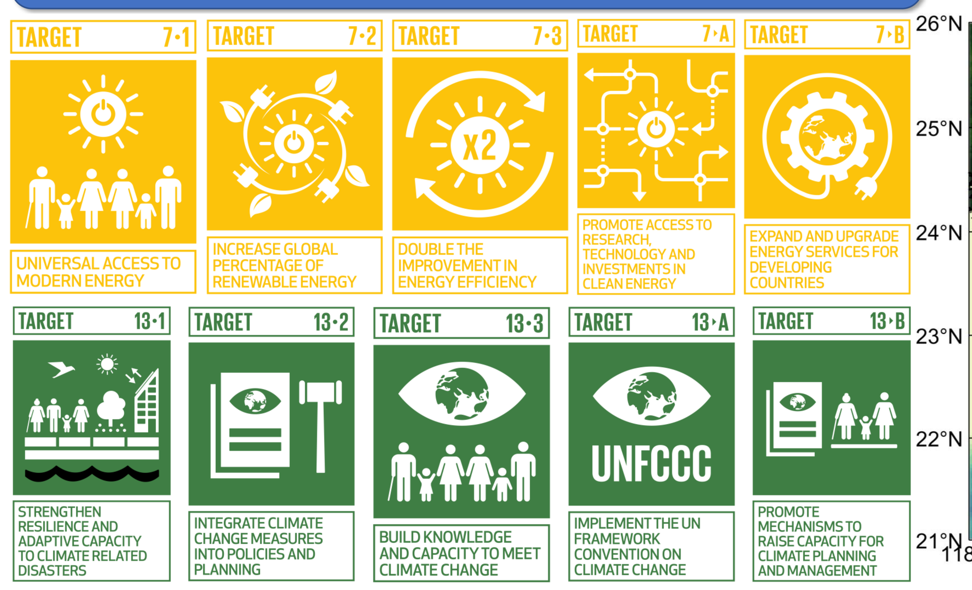
Utilizing Satellite and Meteorological Data to Evaluate Potential Wind Farm and Photovoltaic Panel Sites Inland and Offshore Taiwan

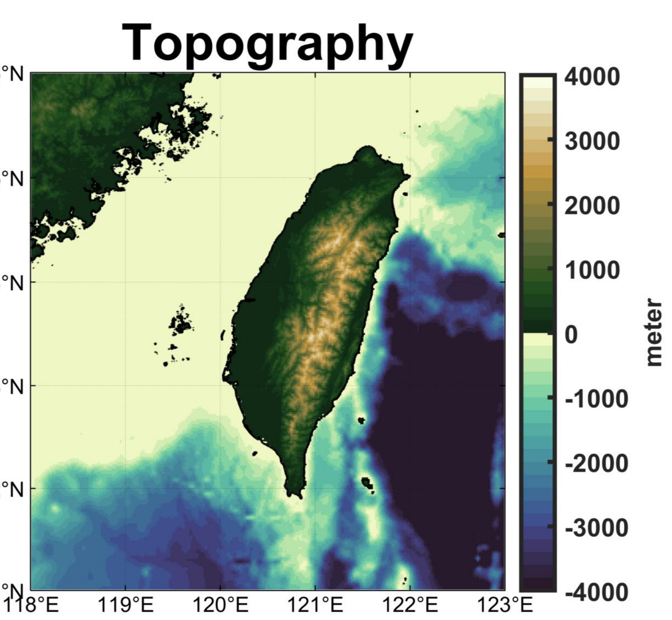
Chih-Yen, WANG[1*] and Po-Chun, HSU[1,2]

[1]Center for Space and Remote Sensing Research, National Central University, Taoyuan City, Taiwan (y2719183@gmail.com)

[2]Institute of Hydrological and Oceanic Sciences, National Central University, Taoyuan City, Taiwan (hpochun@csrsr.ncu.edu.tw)

Background and Study Area





▲ Study Area of Taiwan

Wind and solar energy, as low-cost, renewable, and environmentally sustainable sources, **play a critical role in advancing Sustainable Development Goal 7** by expanding access to affordable and reliable energy, particularly Taiwan, where there is little natural resource. In addition, wind and solar technologies are essential to addressing the urgent challenges of climate change. By **significantly reducing greenhouse gas emissions**, they act as key drivers of the global energy transition, thereby contributing to the achievement of **Sustainable Development Goal 13** and enhancing the resilience of human societies and natural ecosystems to climate-related impacts.

The distance from the coastline is a critical factor influencing the technical feasibility, infrastructure requirements, and economic viability of renewable energy development, particularly for offshore wind energy projects. **Water depth significantly determines the type of offshore wind turbine technology that can be deployed**. Fixed-bottom wind turbines are suitable for water depths of less than 80 meters, providing stable foundations in shallow waters. In contrast, floating wind turbine systems are more appropriate for deeper waters exceeding 80 meters, enabling the exploitation of wind resources in previously inaccessible offshore locations. Currently, the technology for installing solar panels offshore is still under development and has not yet reached commercial maturity. Therefore, **large-scale solar energy installations are primarily concentrated on land-based sites**. To a sum, this study focus on the potential wind farm and photovoltaic panel sites.

Methodology and Data

	Data Source	Wavelength	Data Time	Spatial Resolution	Unit
10m Ocean Wind	SSMI	Microwave	2015/4~ 2024/10 (10)	25km	m/s
	AMSR-2	Microwave			
	GMI	Microwave			
	SMAP	Radio			
	ASCAT	Microwave			
	Copernicus				

▲ Data Source of Wind Speed

Himawari-8, Himawari-9	Spatial Resolution	Data Time	Data	Unit
Short Wave Radiation	5km	H8:2015/7~2022/11 H9:2022/10~2025/1	Level 3 Monthly Data	W/m^2
ECMWF / Copernicus	**Spatial Resolution**	**Data Time**	**Data**	**Unit**
2m Land Temperature	0.1°	2015/7~2025/1	ERA5 Reanalysis Monthly Data	K
Central Weather Administration (CWA)	**Number of Site**	**Data Time**	**Data**	**Unit**
Global Solar Radiation	25	2015/7~2025/1	Observational Accumulate Monthly Data	MJ/m^2

▲ Data Source of Solar Energy Research

➢ **Wind power density (WPD)**

$$E = 0.5\,\rho\,V^3$$

ρ is the air density, 1.225 in default, the unit is kg/m^3. V is the instantaneous wind speed observed among 10m ocean, the unit is m/s. E is the wind power, the unit is W/m^3.

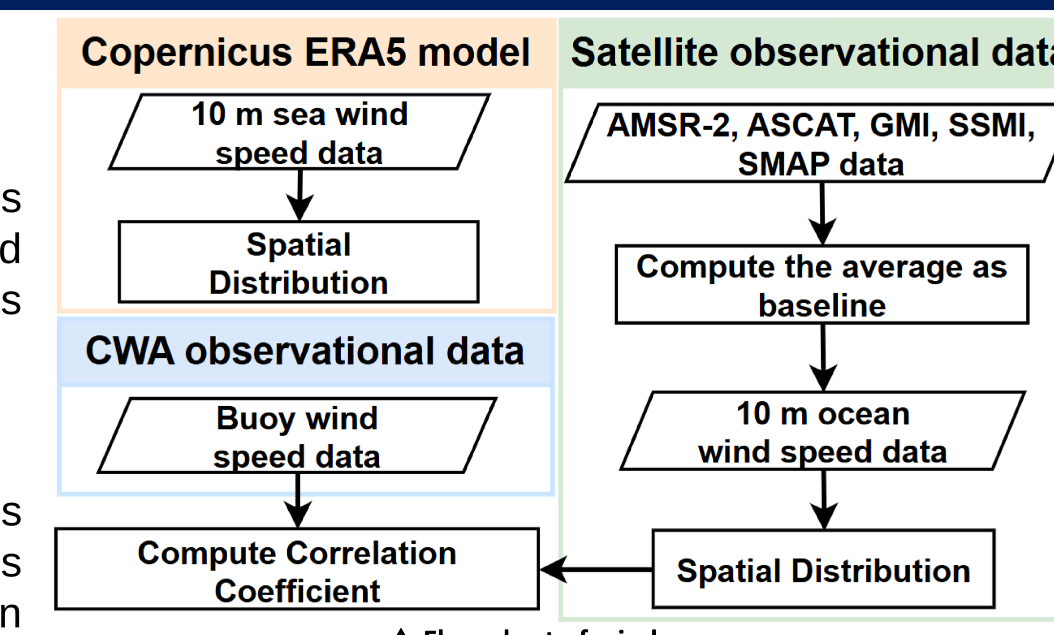
➢ **Power generation of solar energy**

$$Pt = SSR * (1 - ((T - 25°C) * (-0.1\%))) * \eta$$

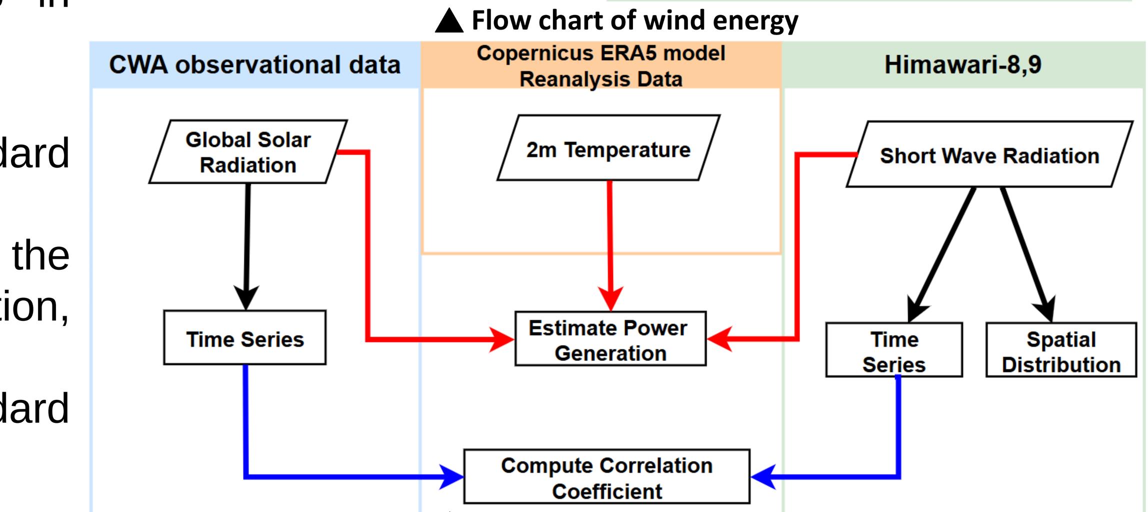
SSR is Short Wave Radiation, unit is W/m^2. T is 2 meter land temperature, unit is Celsius. η is conversion efficiency of solar cells, 15% in general.

➢ **Weights formula**

Level 1: the value < mean value – standard deviation, assigning 1 weights.
Level 2:mean value – standard deviation < the value <= mean value + standard deviation, assigning 2 weights.
Level 3: the value > mean value + standard deviation, assigning 3 weights.



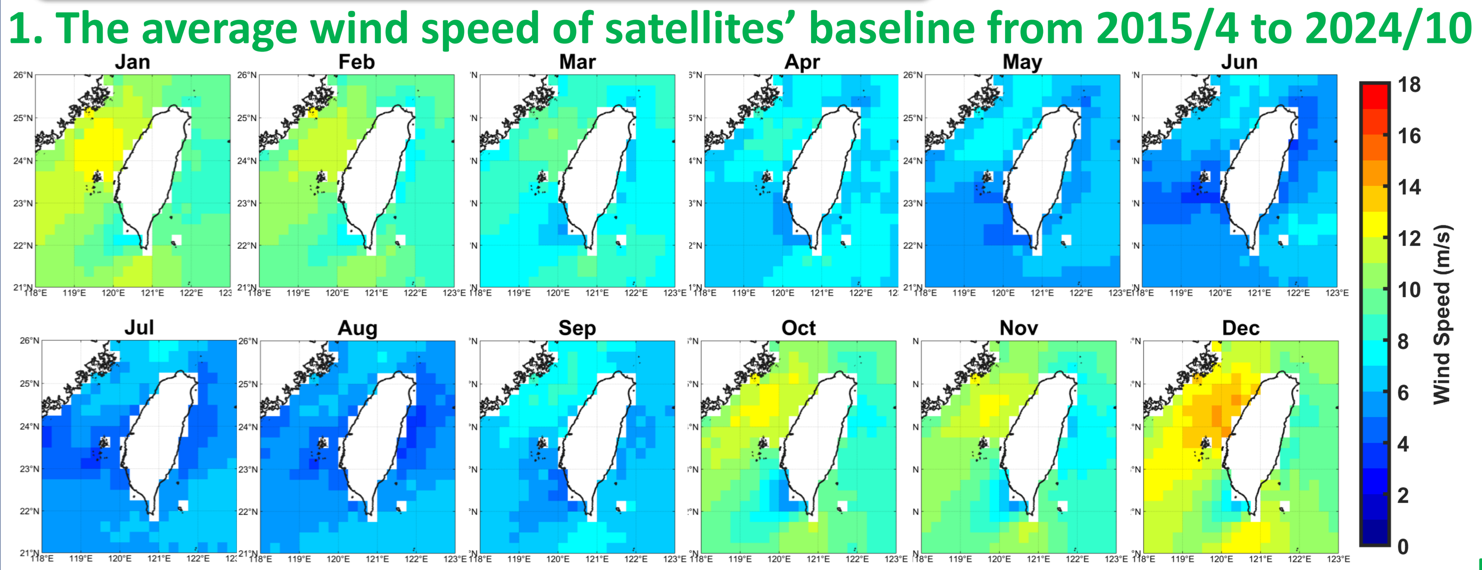
▲ Flow chart of wind energy



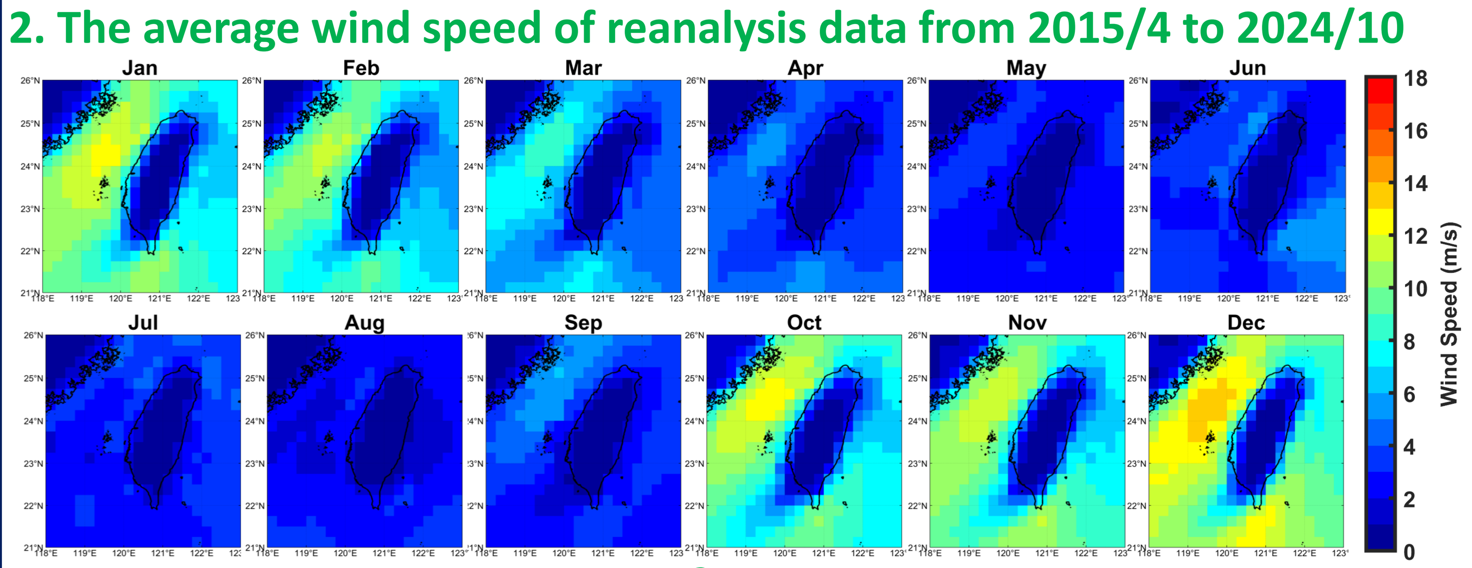
▲ Flow chart of solar energy

Results and Discussion

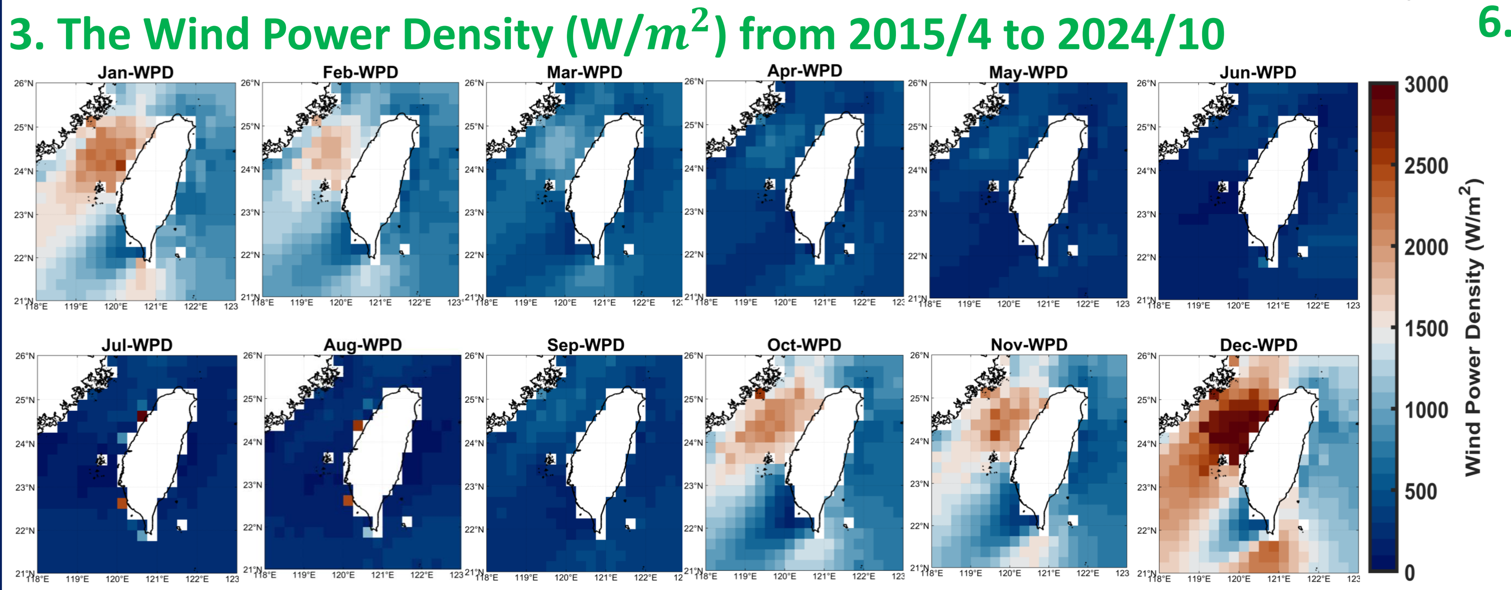
1. The average wind speed of satellites' baseline from 2015/4 to 2024/10



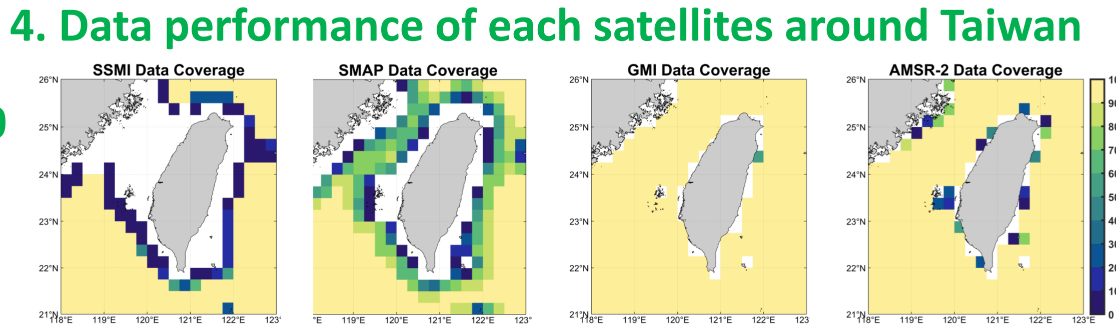
2. The average wind speed of reanalysis data from 2015/4 to 2024/10

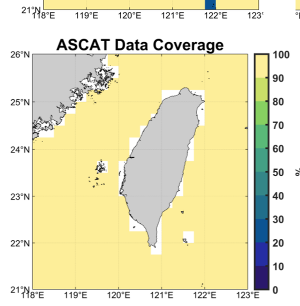


3. The Wind Power Density (W/m^2) from 2015/4 to 2024/10



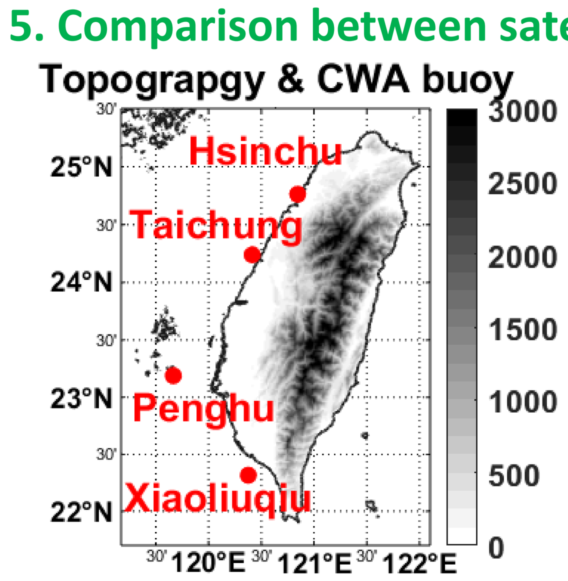
4. Data performance of each satellites around Taiwan





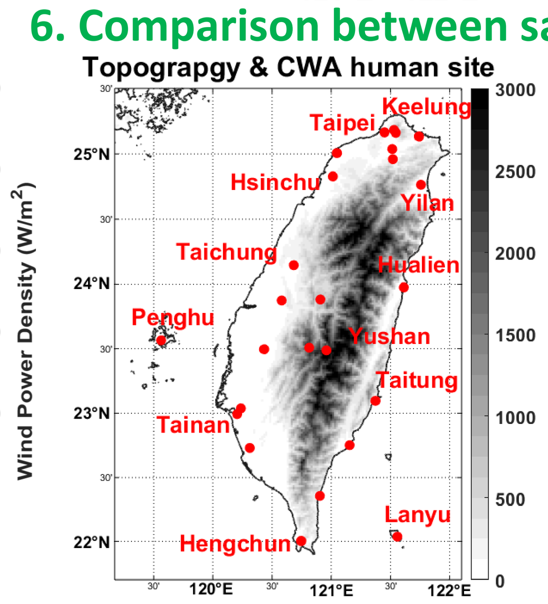
The images illustrate the wind speed data coverage provided by each satellite. SSMI and SMAP have limited capability to observe wind speeds in the Taiwan Strait. Additionally, AMSR-2 struggles to collect data near land. On the other hand, GMI and ASCAT offer comprehensive coverage around Taiwan, unlike the other satellites.

5. Comparison between satellites' wind speed & CWA Buoy



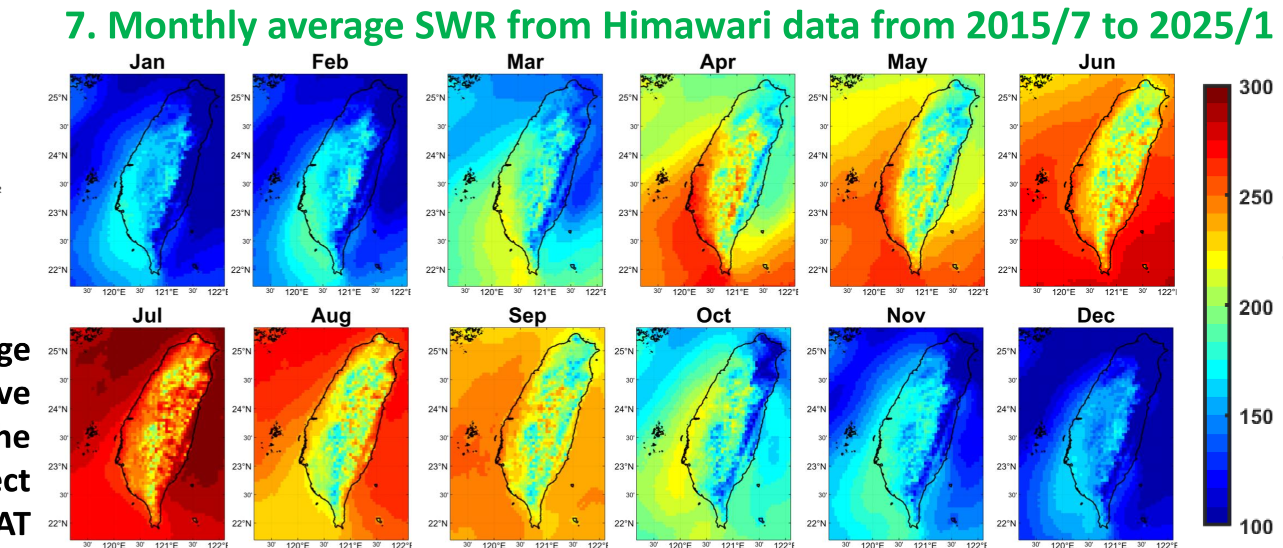
	Hsinchu	Taichung
Correlation Coefficient	0.9	0.93
	Penghu	**Xiaoliuqiu**
Correlation Coefficient	0.97	0.05

6. Comparison between satellites' SWR & CWA GSR

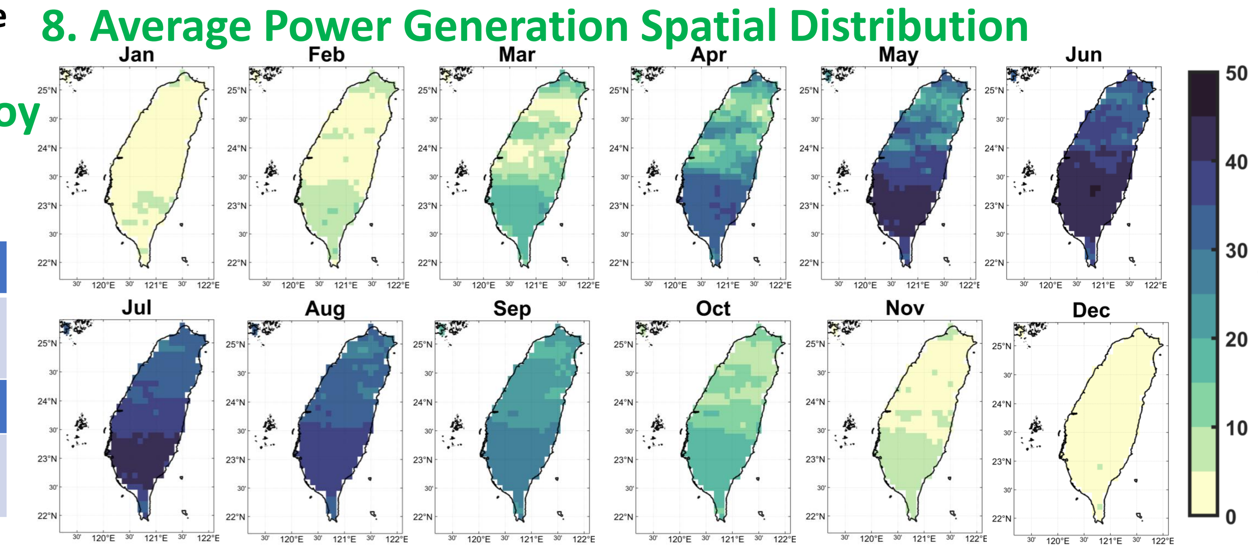


	Keelung	Taipei	Hsinchu
Correlation Coefficient	0.99	0.96	0.94
	Taichung	**Penghu**	**Tainan**
Correlation Coefficient	0.91	0.96	0.90
	Hengchun	**Lanyu**	**Taitung**
Correlation Coefficient	0.84	0.97	0.96
	Hualien	**Yilan**	**Yushan**
Correlation Coefficient	0.94	0.98	0.76

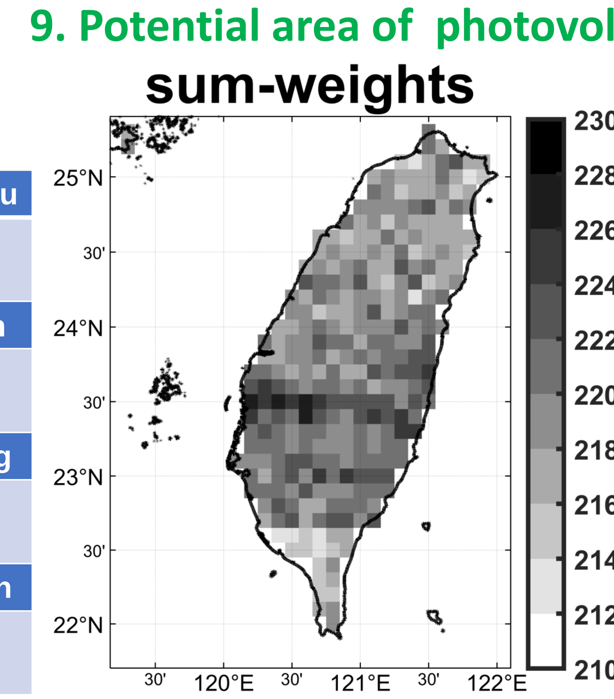
7. Monthly average SWR from Himawari data from 2015/7 to 2025/1



8. Average Power Generation Spatial Distribution



9. Potential area of photovoltaic panels sites



The image on the left-hand side presents a summary of photovoltaic potential weights, based on data collected from July 2015 to January 2025.The potential **weights are calculated by normalizing the monthly mean shortwave radiation values using their respective standard deviations**, allowing for a standardized comparison across different regions and seasons. In the figure, black grid points represent areas with high photovoltaic potential, indicating regions suitable for solar panel installation. **The southwest Taiwan is quite suitable for developing solar industries.**

Conclusions

1. The average of Wind Power Density (WPD) from multiple satellites highlights the **high potential for offshore wind energy in the Taiwan Strait**.
2. The wind speed observes by satellites is **higher** than the reanalysis wind speed during spring and summer, ranging approximately 3m/s.
3. **SMAP and SSMI struggle to capture wind speed data at the Taiwan Strait**, and AMSR-2 cannot cover areas near the land. It shows the difference between each other.
4. The spatial distribution of monthly average SWR aligns a **northeast-southwest direction** because of mountains in Taiwan.
5. A 10-year average power generation indicates that **south Taiwan is suitable for Photovoltaic panel** installation.
6. According to the summary of solar potential weights, **south Taiwan without southernmost area is quite suitable for developing Solar Energy Sector in Taiwan**.

References

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