



ATENEO DE MANILA
UNIVERSITY



SCHOOL OF SCIENCE
AND ENGINEERING



MANILA OBSERVATORY

Characterizing the Historical and Projected Wind Energy Resource in the Philippines Using CORDEX-SEA Simulations

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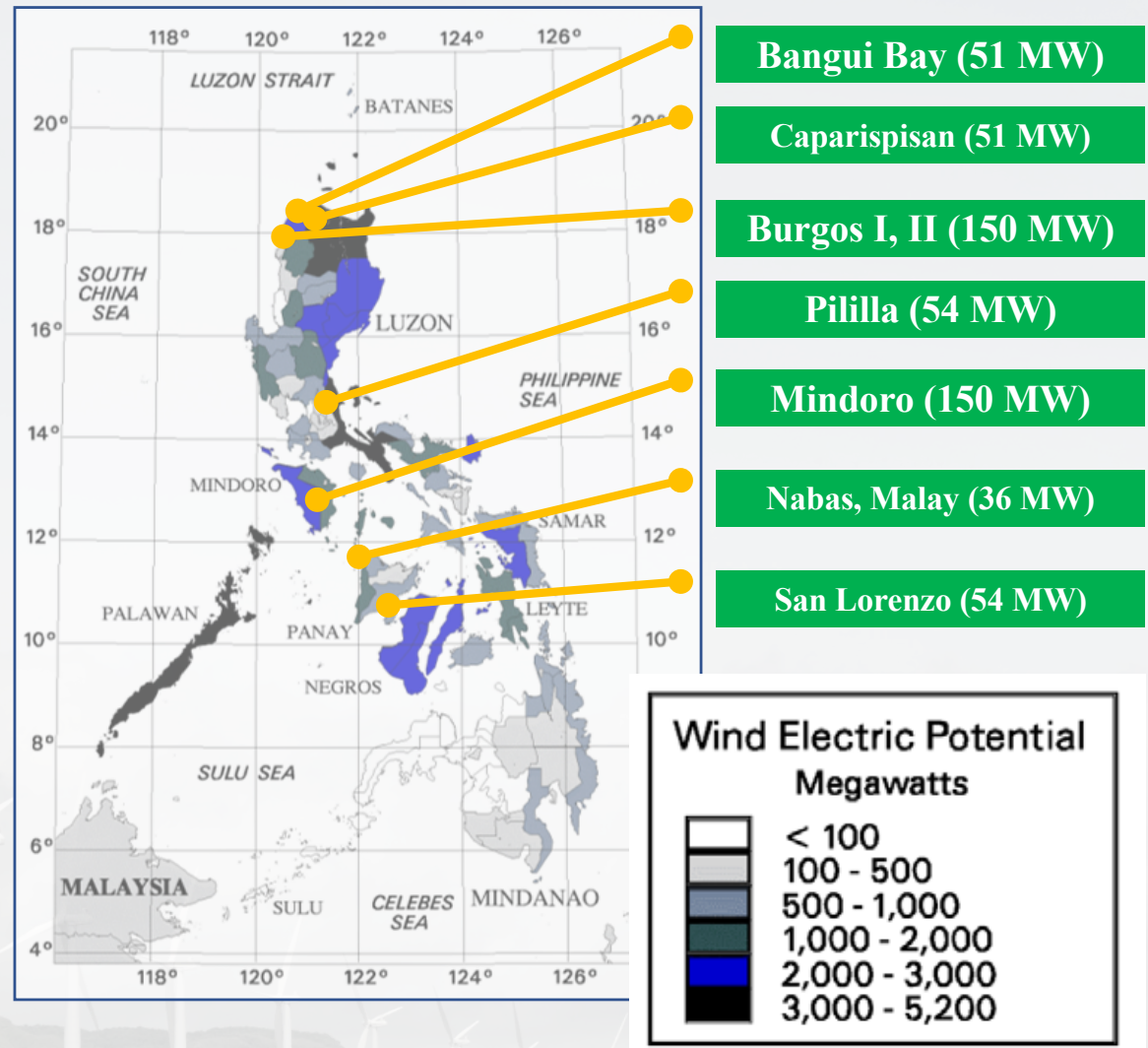


Wind Energy in the Philippines

1999 NREL Wind Energy Atlas: the Philippine region had **11,000 km²** of good windy land areas, which can provide roughly **76 GW** of power

Wind energy resource is expected to change due to climate change

Existing Wind Farms in the Philippines

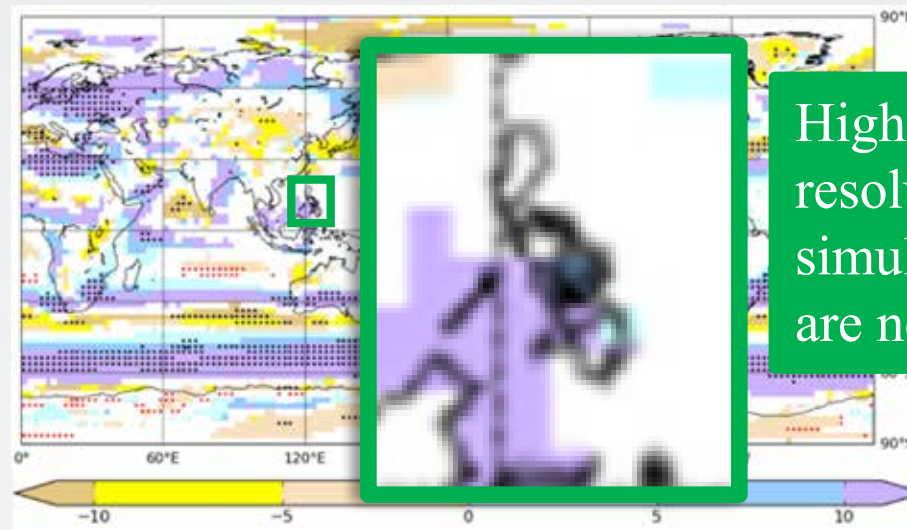


Climate Models to Assess Wind Energy?

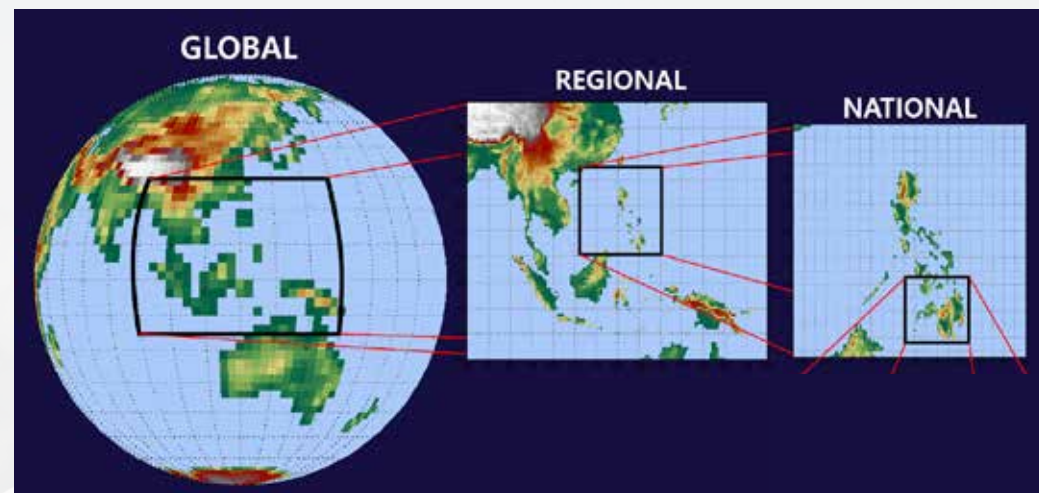
A study using 19 global models from CMIP3 found that SEA and PH wind resource may increase in the future

Right: Global annual surface wind speed change between 2081-2100 and 1981-2011 (McInnes et al. 2011)

Downscaling w/ CORDEX-SEA allows us to examine wind speeds at the regional scale

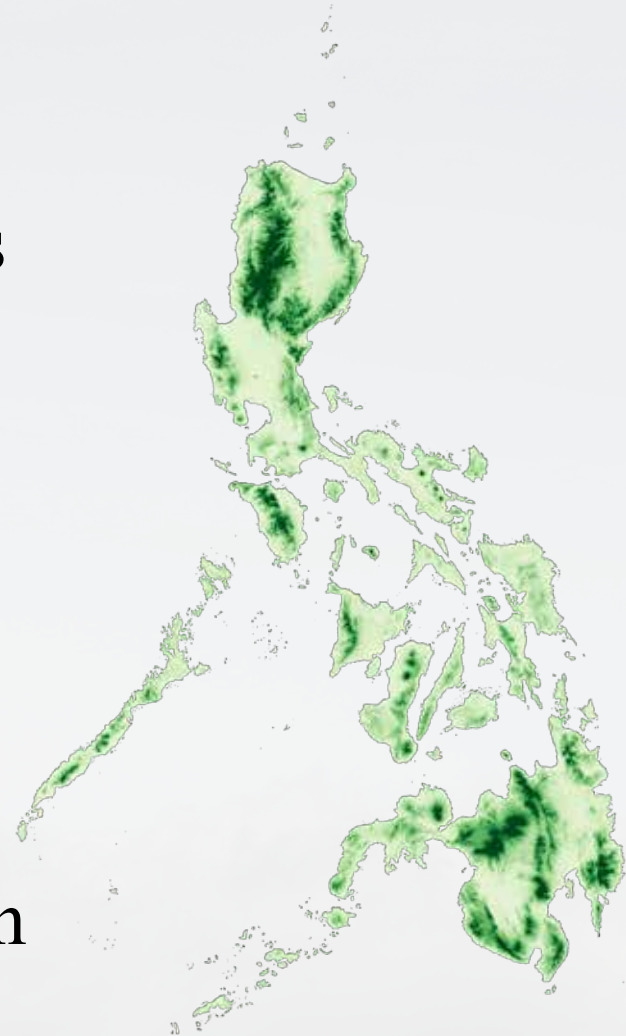


Higher-resolution simulations are needed



What Do We Want to Know?

1. How well do CORDEX-SEA models simulate historical winds in the Philippines (PH)?
2. How will the Philippine wind power potential change due to climate change?
3. Where are the current and future potential wind power locations in the Philippines?



Experiment Design

Datasets

CORDEX-SEA Ensemble
(4 GCMs* downscaled by
RegCM 4.3.3)



Baseline: ERA-Interim



Raw: 10m surface wind speed

Derived: 100m wind speed, 100m wind power density (WPD), extractable wind power (EWP)

***GCMs:** HADGEM2-ES, MPI-ESM-MR, CNRM-CM5, EC-EARTH

Methodology

Historical validation of ensemble wind simulation (1986-2005)



Bias Adjustment w/ Quantile Mapping
(Boe et al, 2007)



Calculation of Historical and Projected
(2026-2045) Wind Power (WPD and EWP) at RCP4.5, RCP8.5



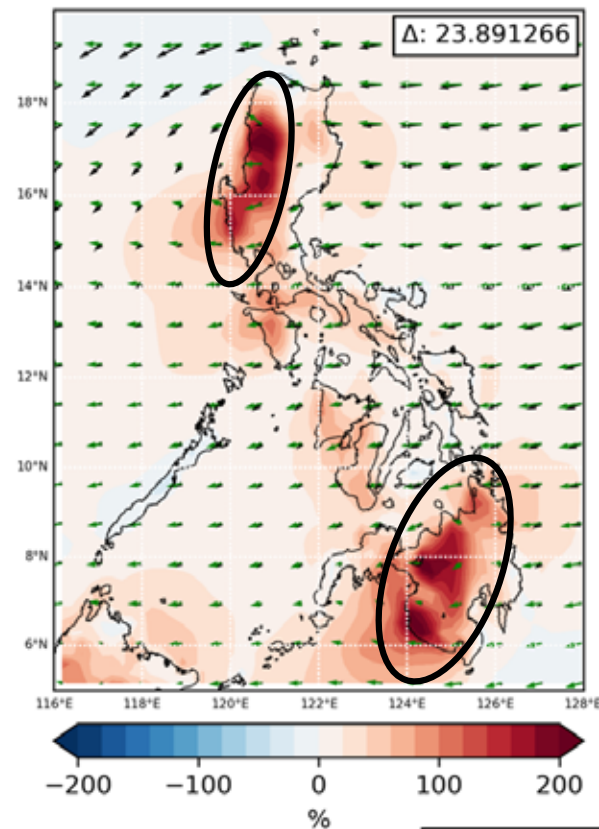
Identification and Analysis of Wind Power Hotspots

wind power hotspots: areas with significant changes in wind power density between the two time periods

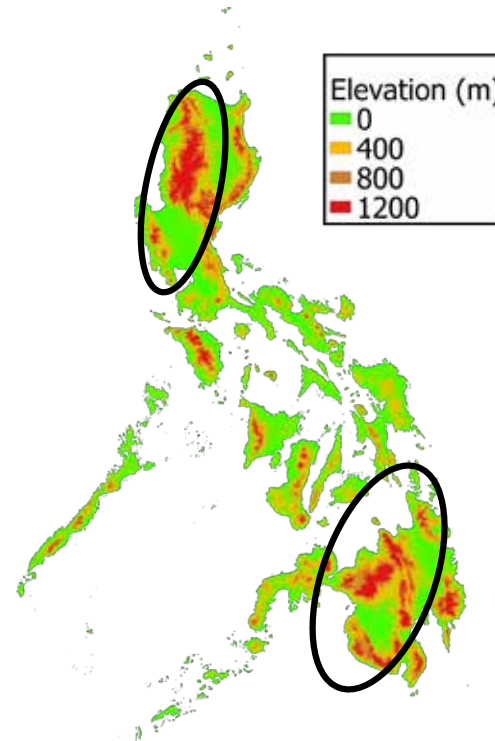
How well does CORDEX-SEA simulate historical winds?

Percent (%) Difference of CORDEX average 10m winds from
ERA-Interim baseline

Original Simulation



PH Elevation (SRTM 90m)

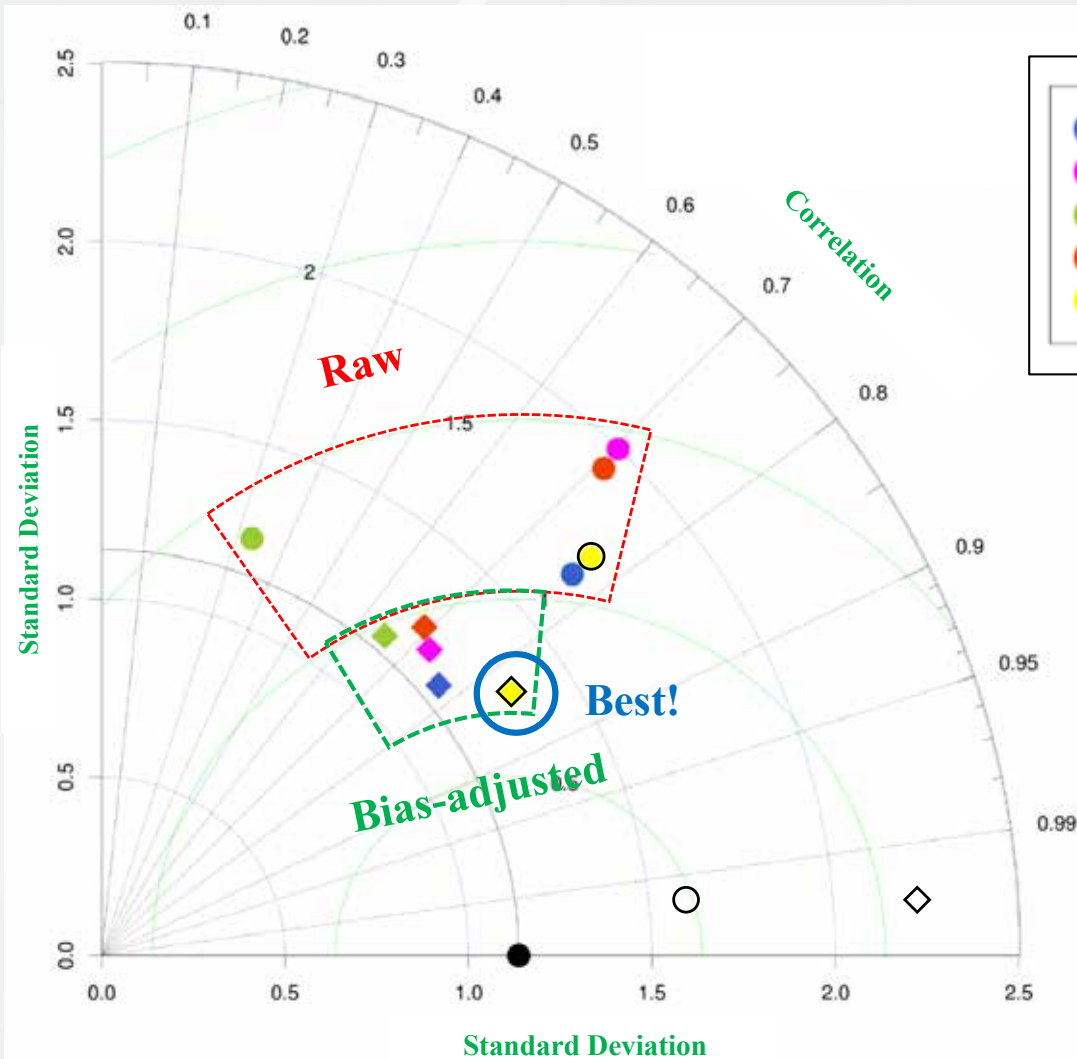


Original: Large overestimation (up to 200%) in W. Luzon & Mindanao (mountainous regions)

Bias-Adjusted: small underestimation (around 10%)

Bias-adjustment also improves wind direction

How well does CORDEX-SEA simulate historical winds?

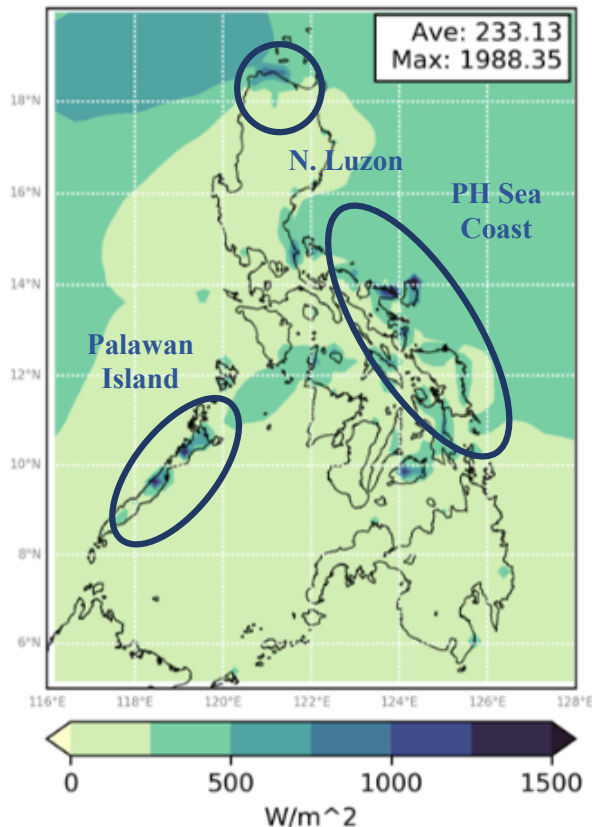


Bias-adjustment: lower bias, higher correlation, and closer variance for all models

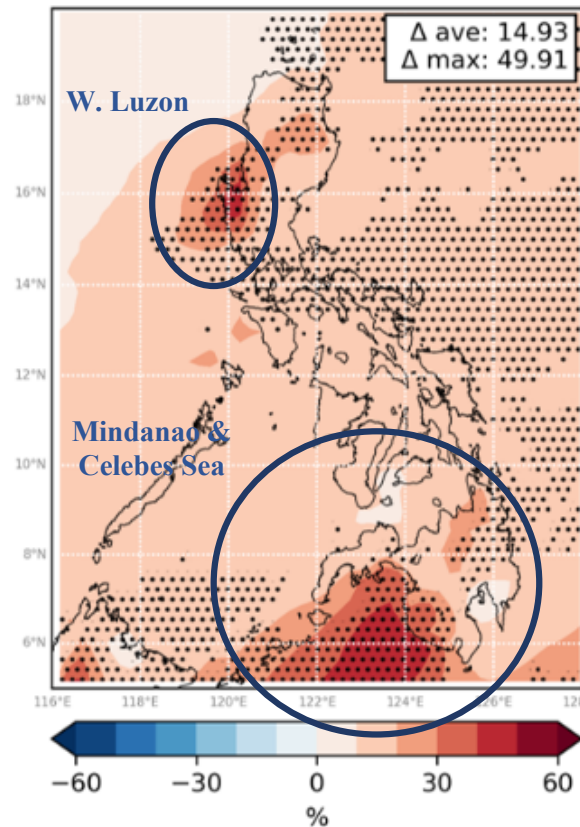
Bias-adjusted ENSEMBLE is best-performing out of all 10 datasets

How will PH wind power change over time?

100m WPD
(2026-2045)



100m WPD % Change
(rel. to 1986-2005)



Wind Power Density (WPD)

- Power generated per unit swept area of turbine blades

$$WPD = \frac{P}{A} = \frac{1}{2} \rho v^3$$

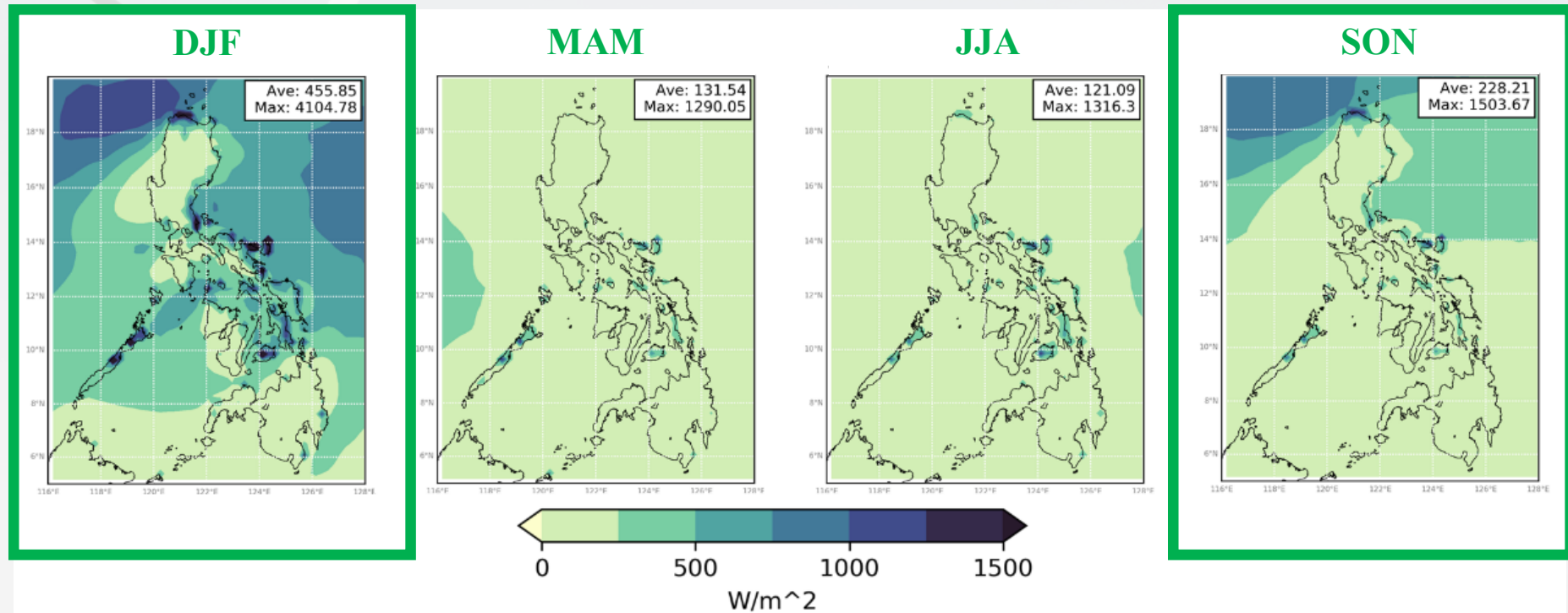
Increase in wind power density over whole Philippine domain

WPD is highest in Northern tip of Luzon, Palawan Island, PH Sea coast

Highest changes in West Luzon, Mindanao, Celebes Sea

How will PH wind power change over time?

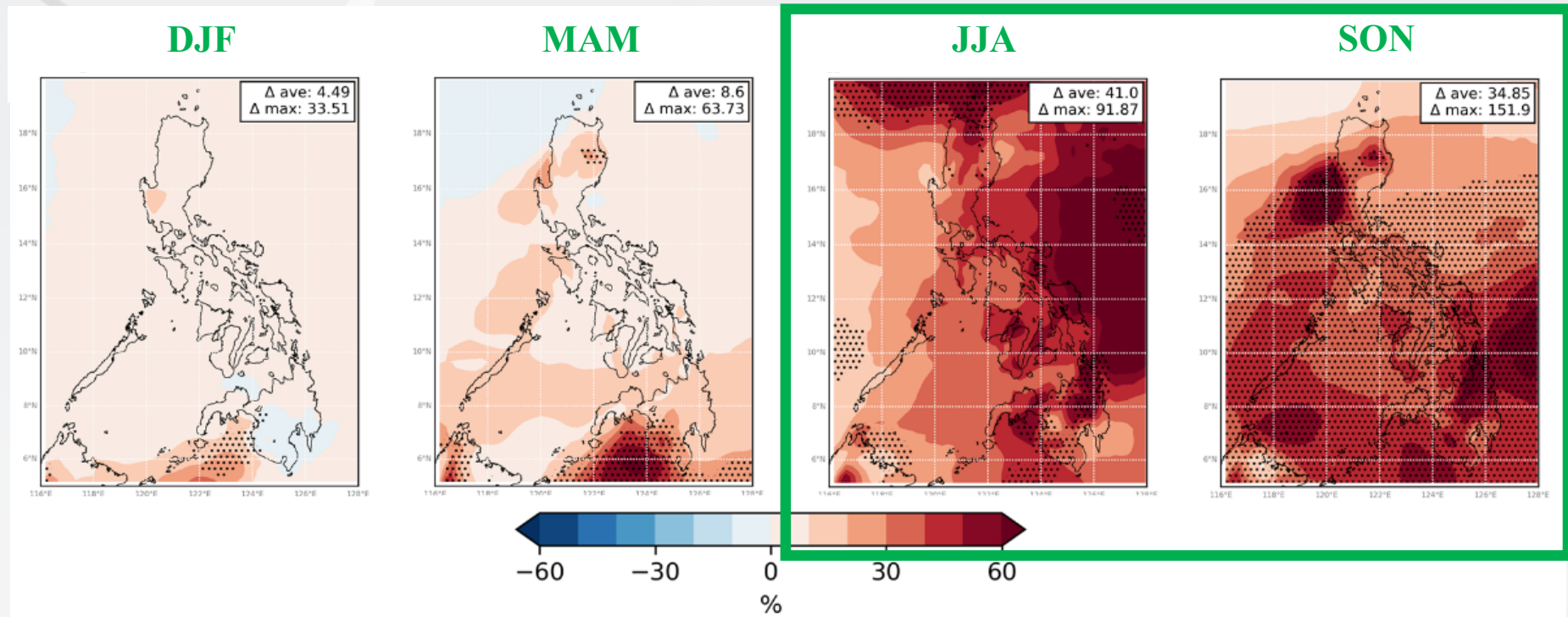
2026-2045 Seasonal 100m Wind Power Density (WPD)



Highest WPD in September – February

How will PH wind power change over time?

2026-2045 Seasonal 100m WPD % Change from Historical (1986-2005)

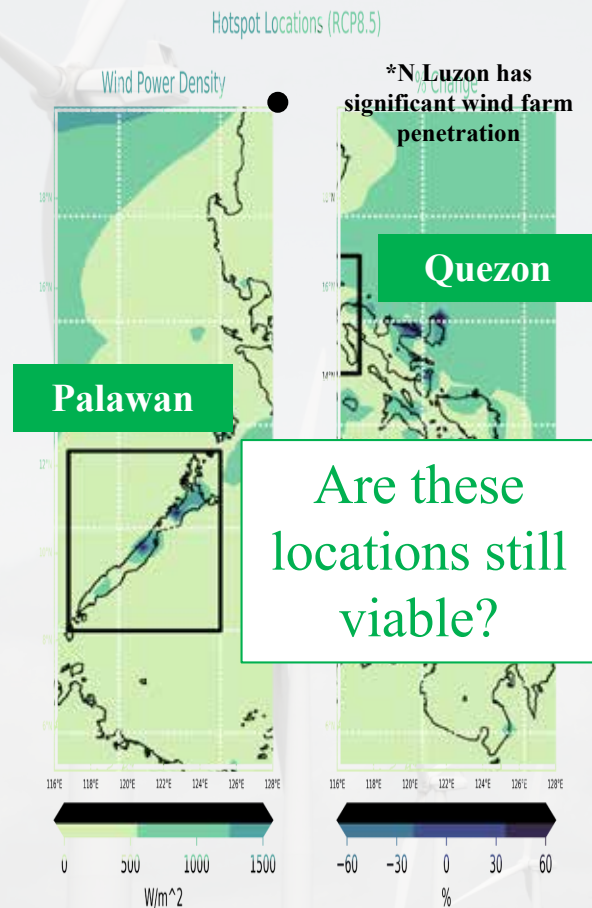


Highest significant WPD increase in June – November

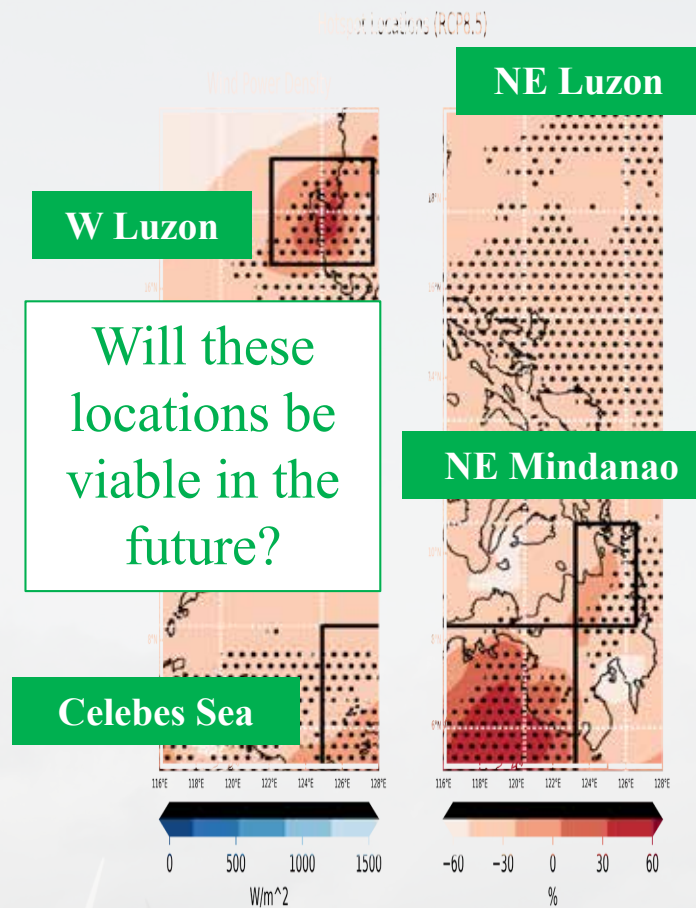
Where are potential PH wind farm areas?

6 total hotspots studied!

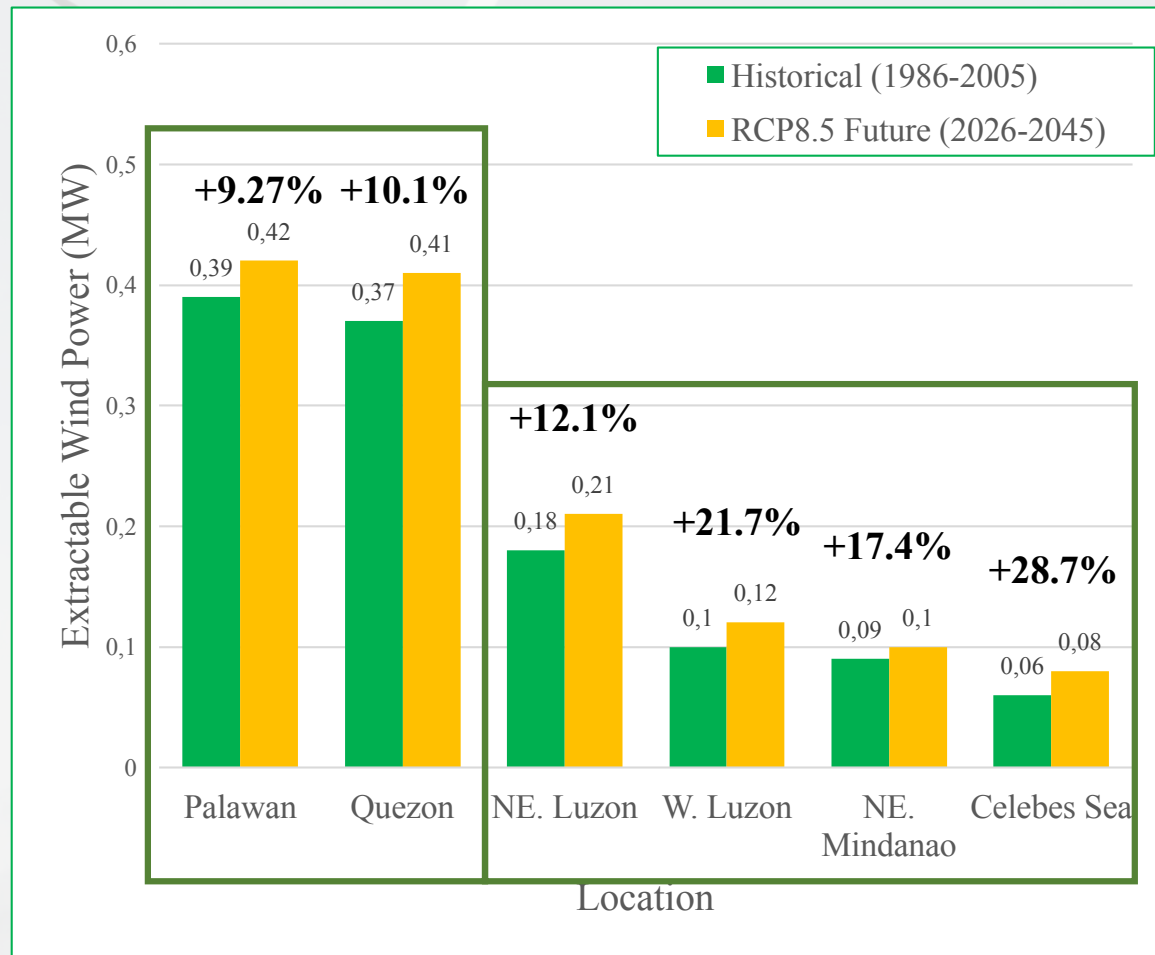
NREL Sites



High WPD % Change Sites

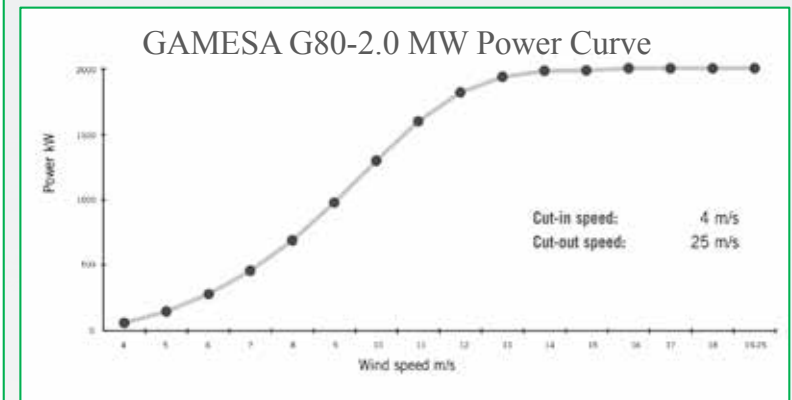


Where are potential PH wind farm areas?



Extractable Wind Power (EWP)

- Actual power generated by turbine (less than WPD)

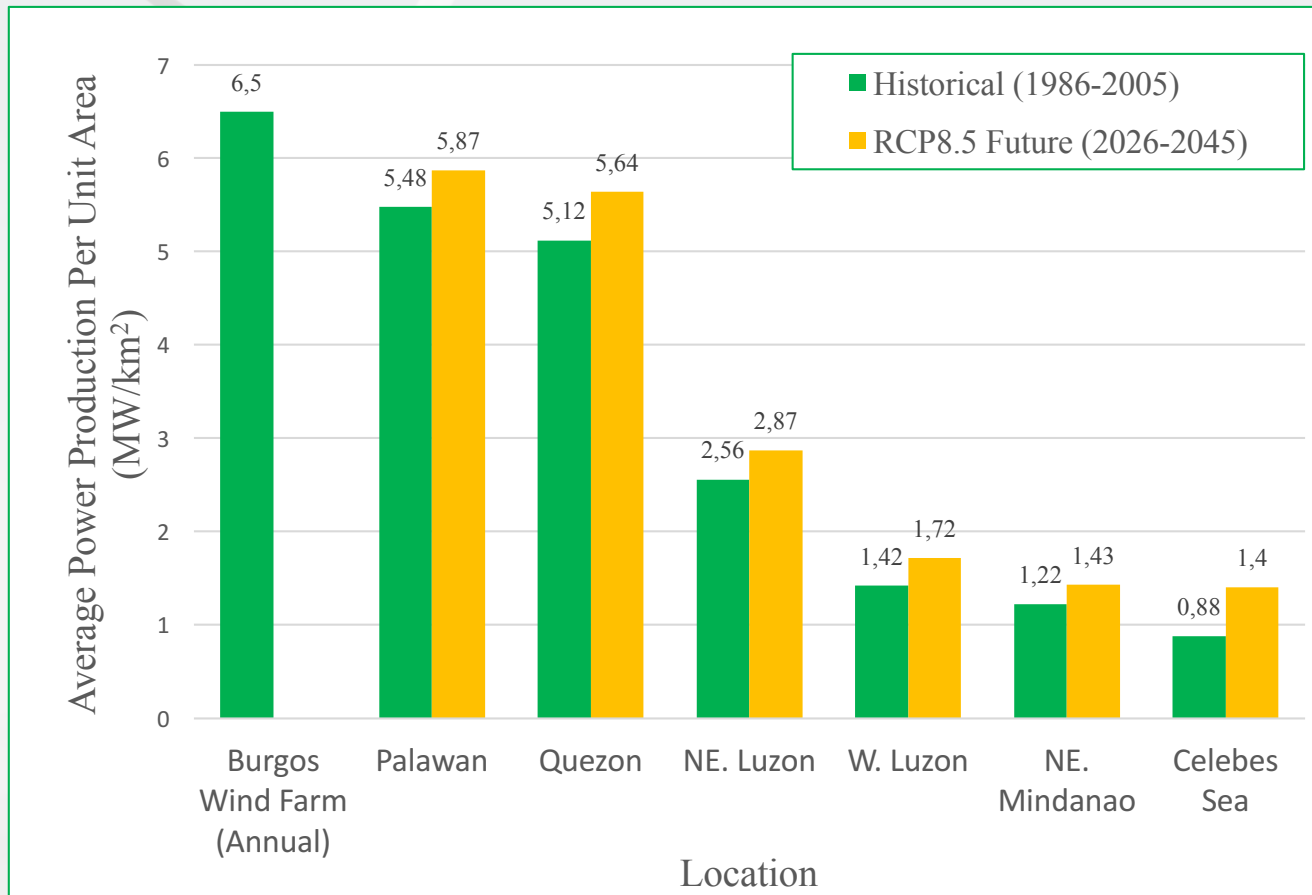


NREL Sites (Palawan & Quezon): high EWP, lesser % increase

Other sites: low EWP, higher % increase

How do areas compare w/ current PH wind farms?

Historical and Projected Potential Power Production



Burgos Wind Farm (150MW): Largest wind farm in SEA

Palawan and Quezon: comparable production to Burgos Wind Farm

Other hotspots have much lower production
• *Worst: Celebes Sea*

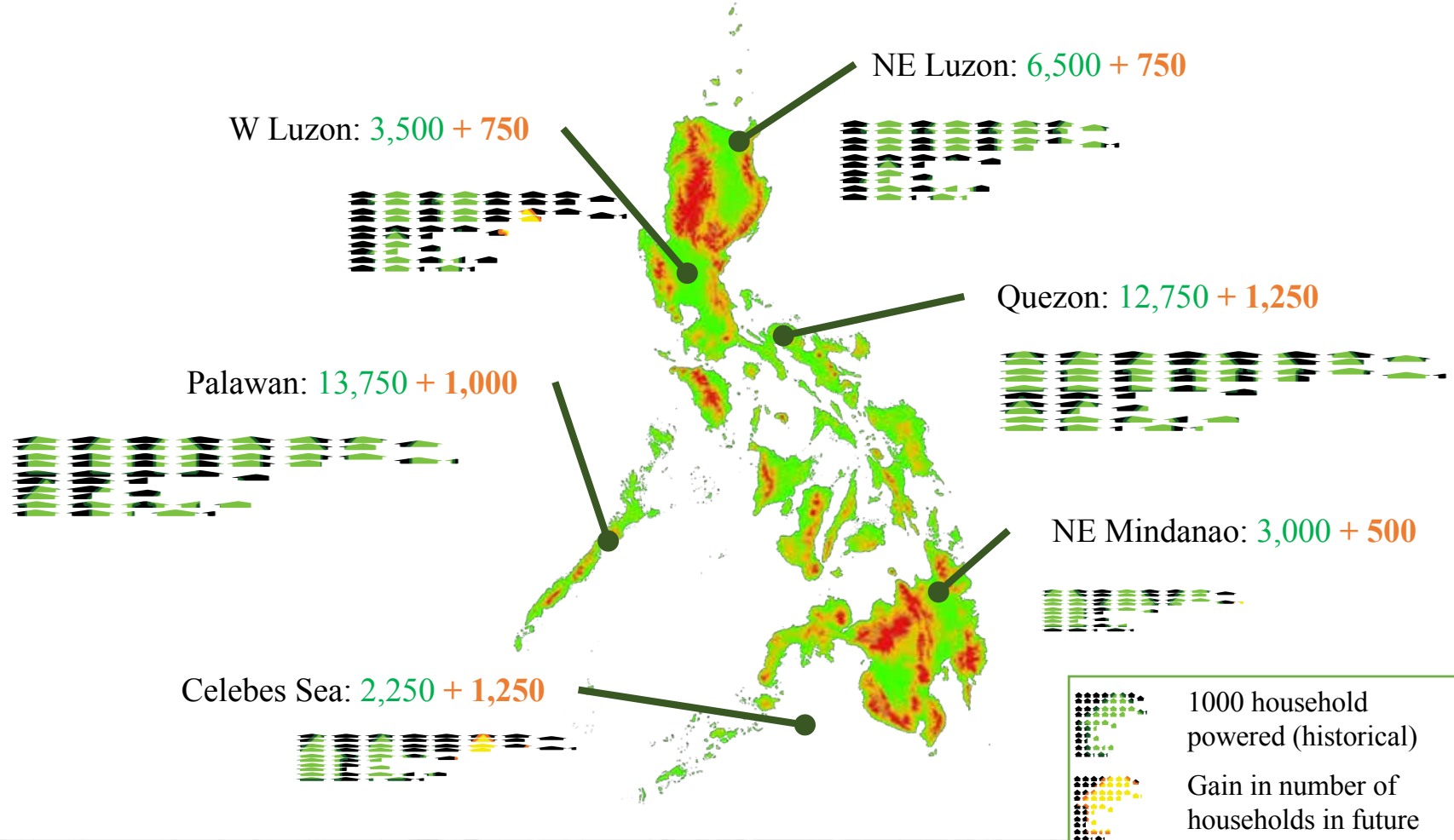
Assumption: 13.9 turbines / sq. km (based on NREL Wind Power Atlas)

1 MW of wind power = 2500 PH households for a year (based on 2015 power consumption and census)

Gain in Households Powered

Households Powered by 1 sq.km of Wind Turbines

(1 MW = 2500 households; 13.9 turbines per sq. km)



Conclusions

1. How well do CORDEX-SEA models simulate historical winds in the PH?

*CORDEX-SEA ensemble overestimated observed wind speeds by **more than 200%***

*Per-model Quantile-Mapping Bias-adjustment reduces ensemble bias to **around 10%***

Conclusions

2. How will the PH wind power potential change due to climate change?

*CORDEX-SEA projections show **increase in wind power density over whole PH domain***

WPD magnitude is strongest during September – February , with stronger WPD increase during June - November

Conclusions

3. Where are the current and future potential wind power locations in the Philippines?

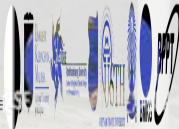
Previously identified hotspots (Palawan, Quezon) will remain good wind farm areas

Despite large increases in wind power density, identified hotspots in this study are still not viable as good large-scale wind farm areas.

*However, possibility of **smaller scale generation** can be explored.*

Maraming Salamat Po!

Thank you very much!



ICRC-CORDEX 2019

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Supplementary Slides



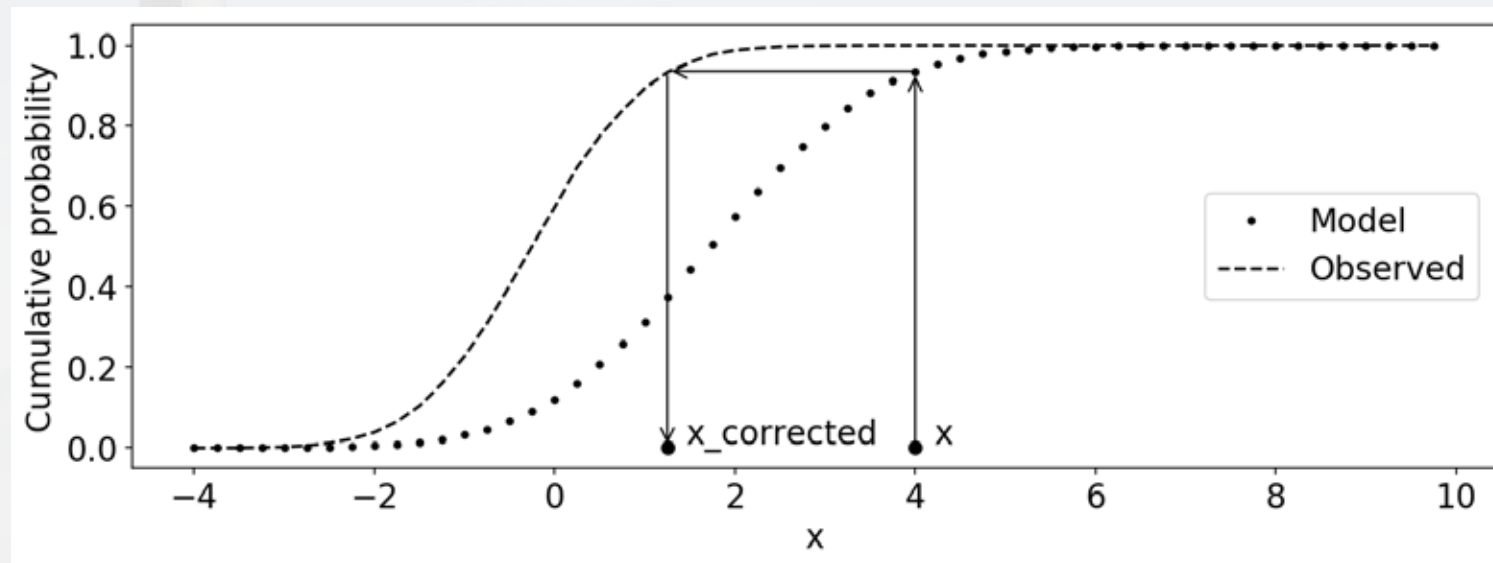
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Bias Correction

Quantile-Quantile Mapping Method (Boe, et al. 2007)

- *Removes biases by equating the cumulative density functions of the model and observed data*
- *Generated transfer function can then be applied for model data of any period*



$$\hat{x}_{model,projected} = CDF_{obs,hist}^{-1} [CDF_{model,hist}(x_{model,projected})]$$

Extrapolating Wind Speeds

Logarithmic Wind Profile

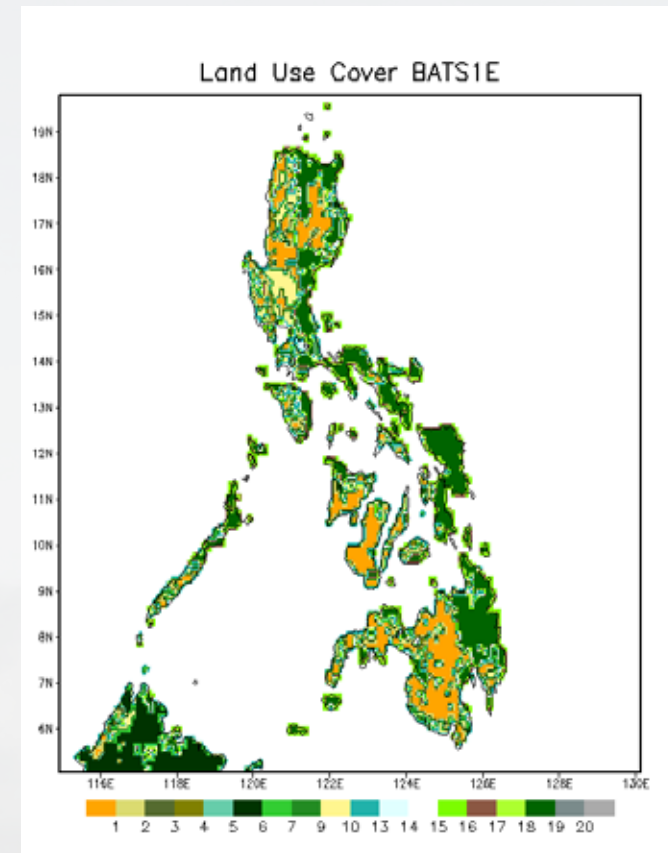
Semi-empirical relationship that allows us to extrapolate wind speeds at higher heights considering surface friction

$$v_{100} = v_{10} \frac{\ln(100m/z_0)}{\ln(10m/z_0)}$$

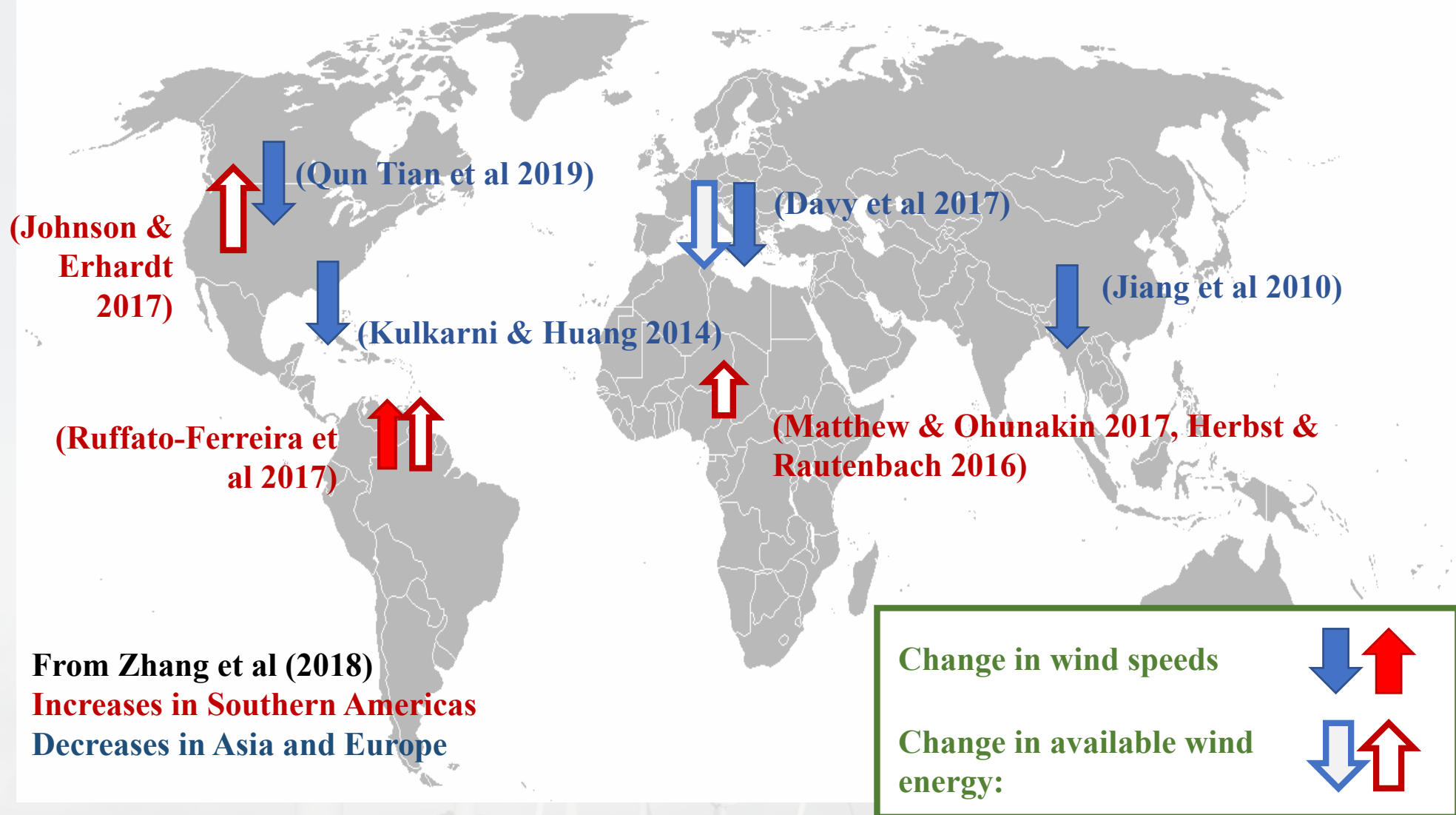
Roughness Length, z_0

Surfaces are rougher if they have more protrusions/obstacles to flow!

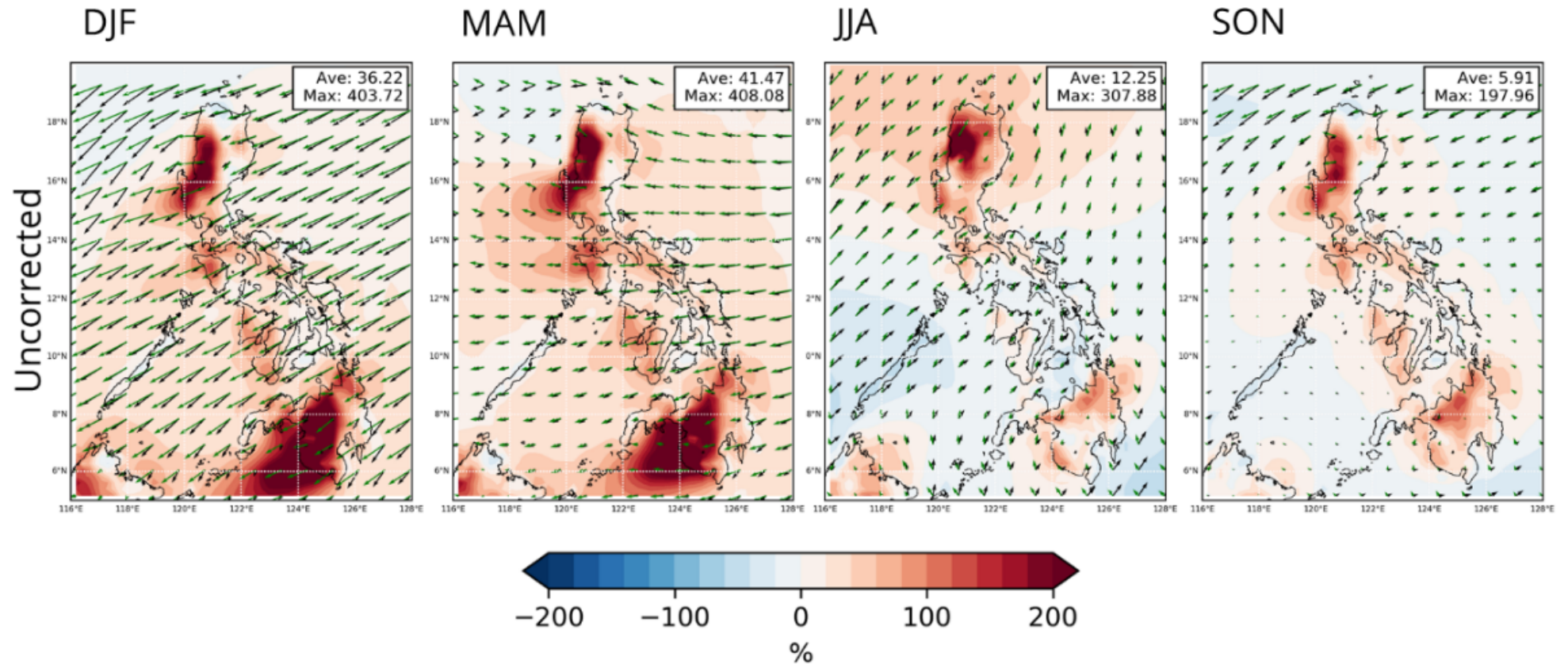
*Assigned per grid-point using **BATS1e***



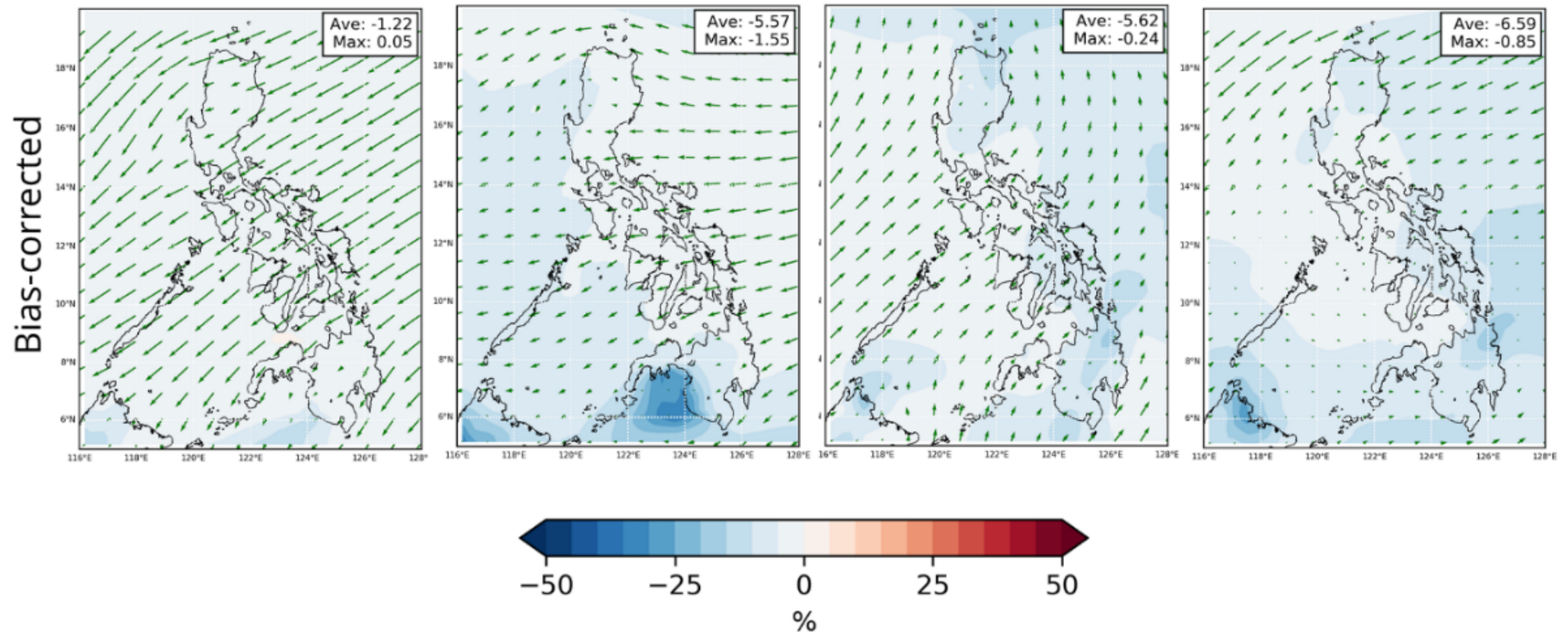
Climate Models to Assess Wind Energy?



% Difference in 10m winds (Ensemble-EIN25), Seasonal



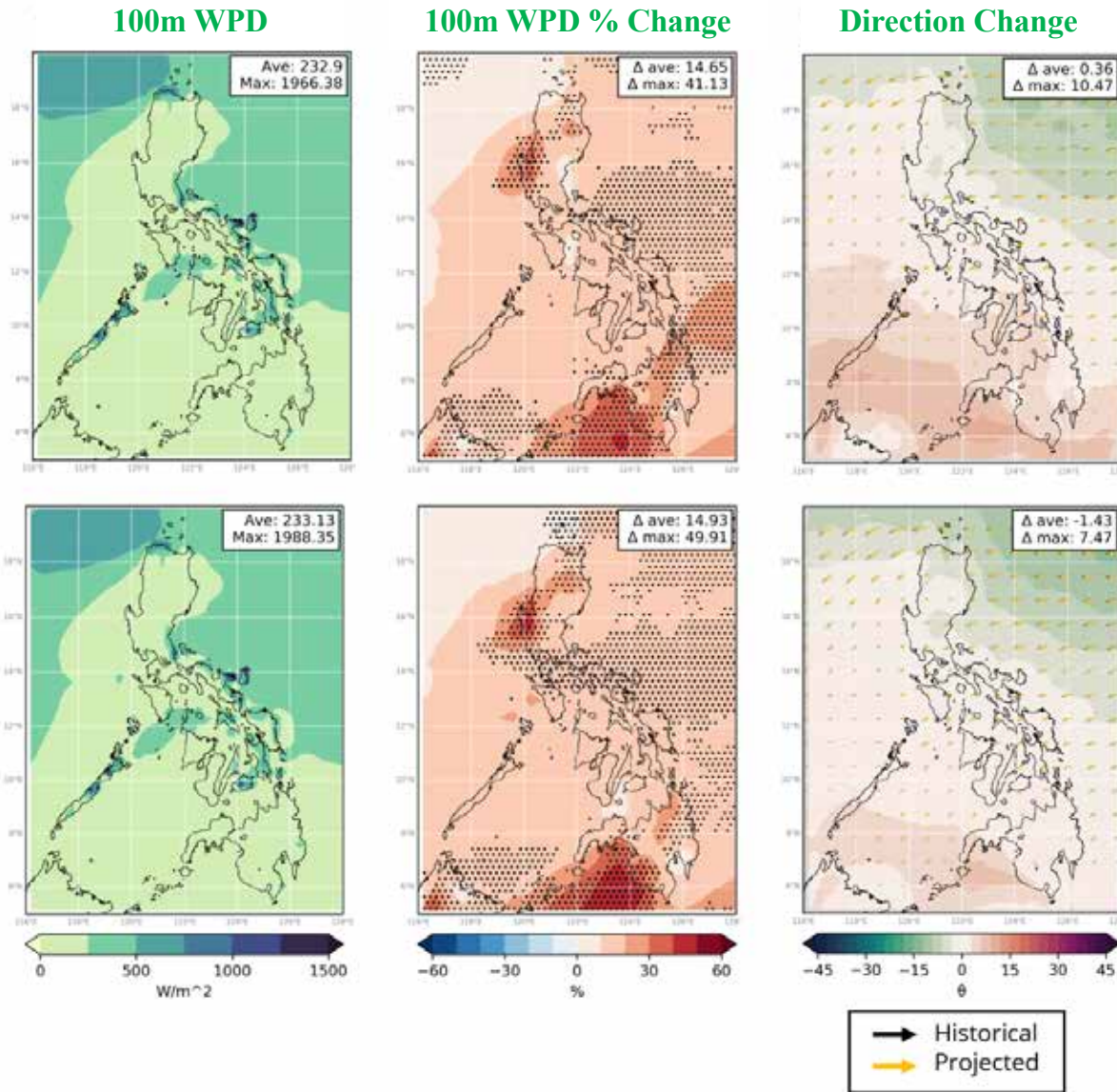
% Difference in 10m winds (Ensemble-EIN25), Seasonal



How does CORDEX simulate future wind?

RCP4.5

RCP8.5



No appreciable difference between RCP4.5 and RCP8.5

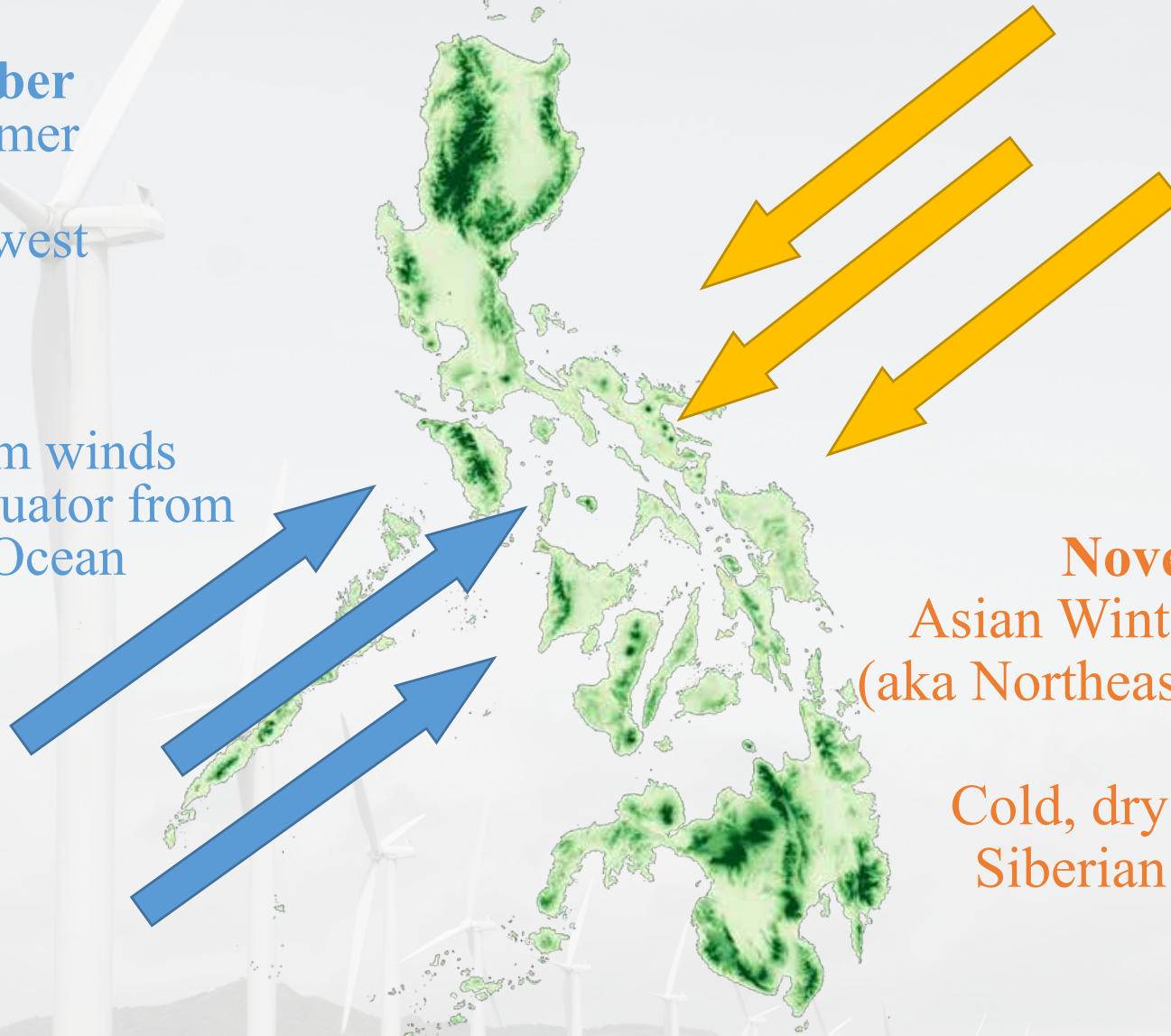
Wind Systems in the Philippines

June-October
Asian Summer
Monsoon
(aka Southwest
Monsoon)

Moist, warm winds
crossing equator from
the Indian Ocean

November-May
Asian Winter Monsoon
(aka Northeast Monsoon)

Cold, dry winds from
Siberian anticyclone



How will PH wind power change over time?

Figure 3: 2026-2045 100m Wind Power Density (WPD), WPD % Change and Wind Direction Change with respect to historical period 1986-2005

