Development of Climate Services for Renewable Energy: Statistical Post-processing of Solar Radiation Seasonal Forecast Over the Indonesian Region

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Background

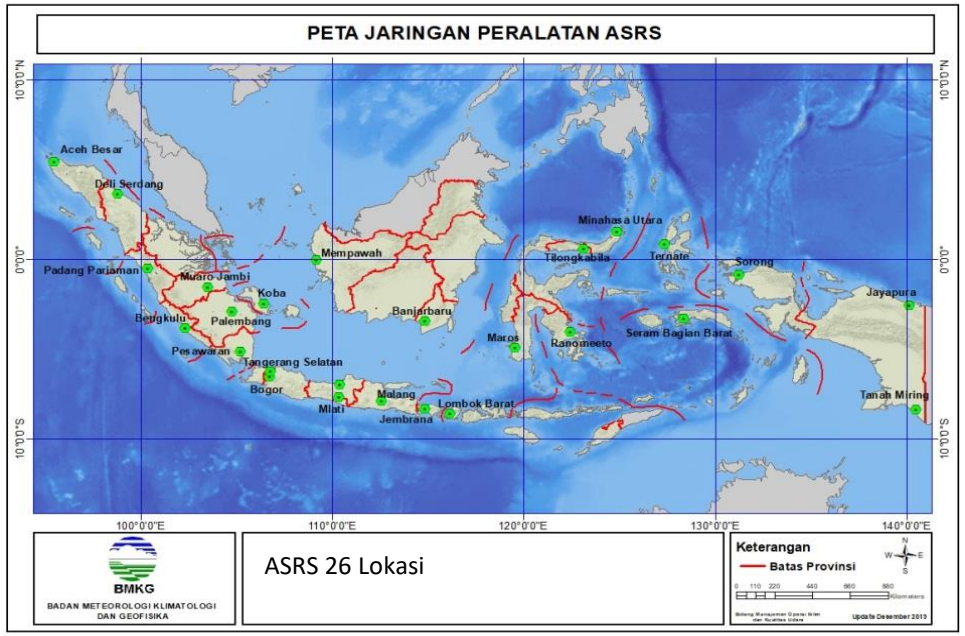
- Climate information services for the renewable energy sector have been carried out within the Center for Applied Climate Information Services since 2016.
- The results of discussions with potential stakeholders provide an overview of the information needs in the renewable energy sector.

Rekomendasi

1. Informasi iklim yang dibutuhkan dalam sektor energi terbarukan antara lain: *irradiance* (W/m^2), waktu efektif radiasi (jam/hari), suhu rata rata harian, arah dan kecepatan angin, *clearness index*, frekuensi dan intensitas tutupan awan.
2. Perlunya kajian Bersama dengan user untuk:
   a) menajamkan informasi terkait potensi energi terbarukan di lokasi yang dibutuhkan.
   b) menyediakan forecast "total potensi energi" harian (yang mungkin dapat dipanen) untuk 1 bulan.

One of the information needed:
monthly total energy potential forecast

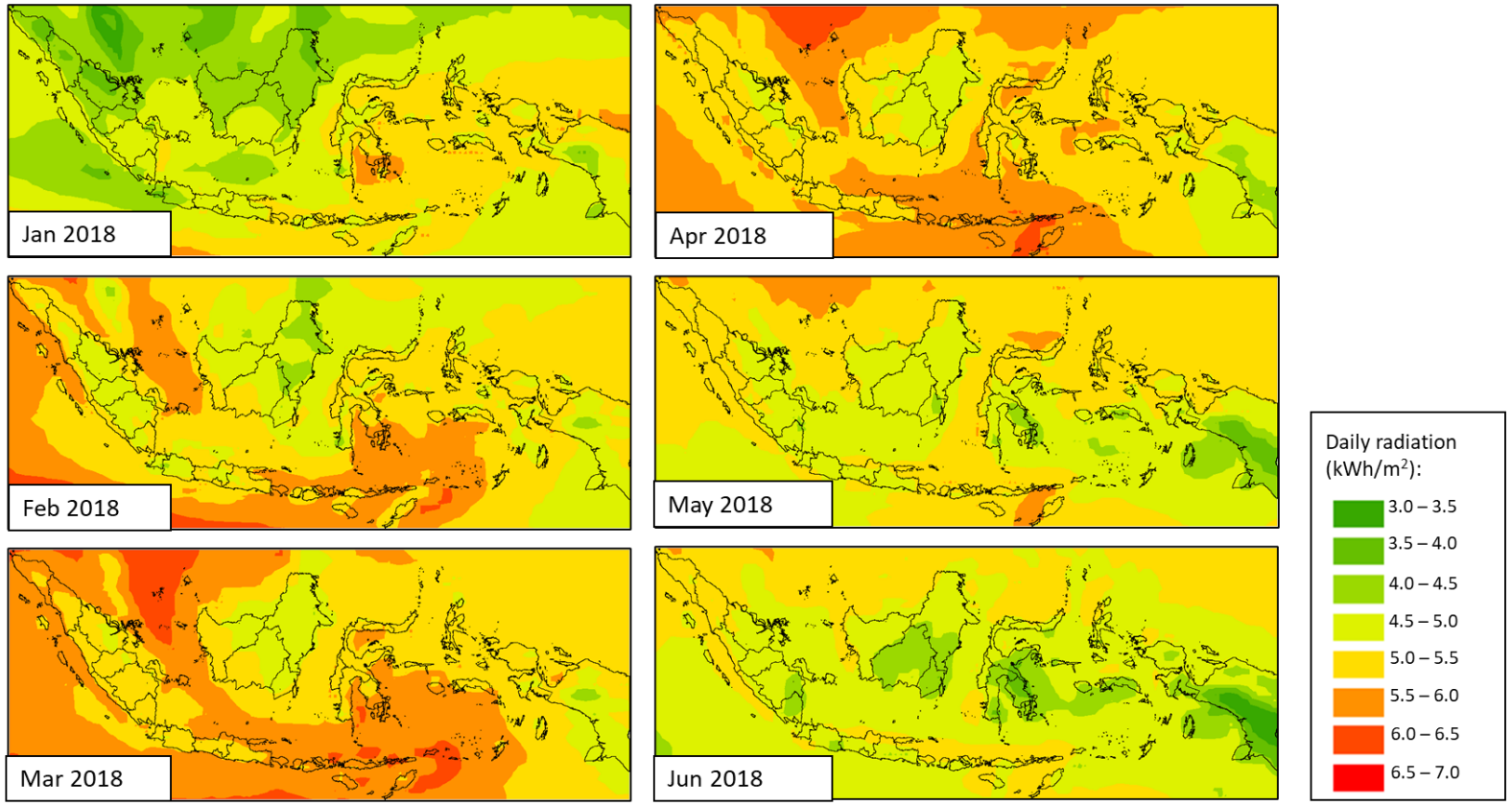
Solar radiation observation network



- New sets of instruments were installed in 27 locations in Indonesia since 2017 to provide radiation data (global, direct, diffuse) with high temporal resolution.
- One station was proposed to be a part of the BSRN network but still on pending status.
- Data from this network of observation had been used to derive the relationship between solar radiation and other meteorological parameters to create solar energy potential map.

ECMWF Seasonal Forecast

Initial running time: January 2018
Daily average of solar radiation



- Accumulated Surface solar radiation downward (SSRD) forecast in J/m^2.
- Obtained every first day of each month for 7 months ahead. Native resolution 0.4^o X 0.4^o
- Previous evaluation shows that model tends to underestimate daily solar radiation when cloud cover is minimum and overestimate when cloud cover is high.

Creating “blended” radiation data

- To reduce systematic bias from the model, bias-correction method was applied using the historical dataset of solar radiation.
- To create gridded observation data, a co-kriging interpolation of the ground-observed solar radiation was implemented with ERA-5 solar radiation data as an external drift in the interpolation process.

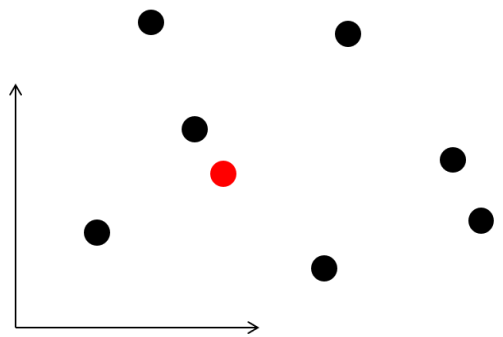
BMKG

(Uni)variate kriging with external drift

- Values at points to be interpolated is estimated as a linear combination of known sample (data):

$$z(\mathbf{u}) = \sum_{j=1}^{n(\mathbf{u})} \lambda_i z(\mathbf{u}_i)$$

- $z(\mathbf{u}_i)$: known values
- $z(\mathbf{u})$: unknown value

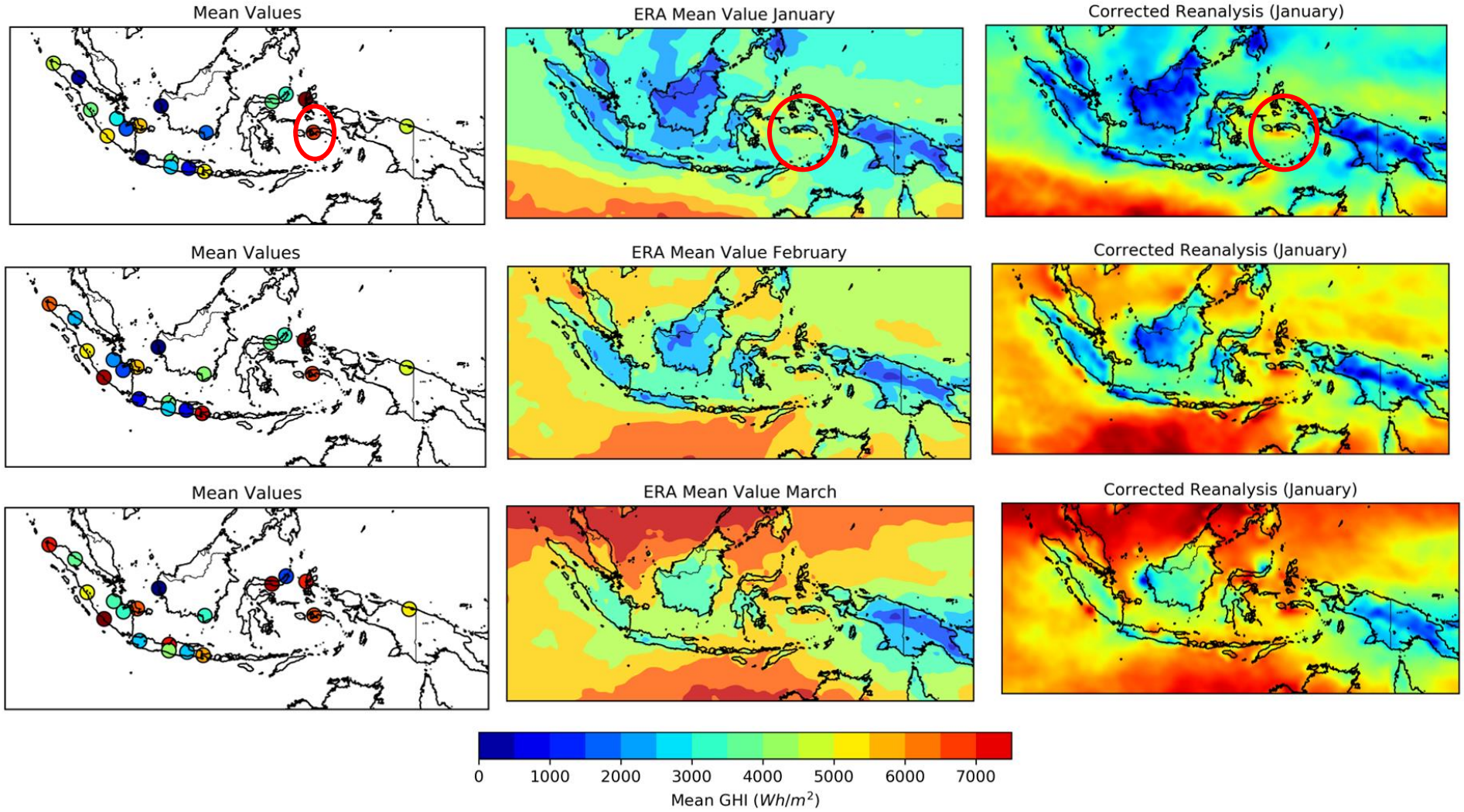


- λi should have a dependence on distance between the **RED** dots and the **BLACK** dots.
- λi in this case should be inversely proportional to the distances.

Badan Meteorologi Klimatologi dan Geofisika

Courtesy of A. Sopaheluwakan

Creating “blended” radiation data



Bias-correction process

- The bias-correction process was done by creating an analytical transfer function that represent the relationship between the statistical moments of both the numerical model output and observed radiation based on its probabilistic distributions.
- To apply these calculations, it is assumed that solar radiation data is normally distributed.

CDF of normally distributed data, denoted as $\Phi(x)$, can be written as:

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-t^2/2}\, dt$$

The closely related error function, $\mathrm{erf}(x)$, can be written as:

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_{0}^{x} e^{-t^2}\, dt$$

that gives:

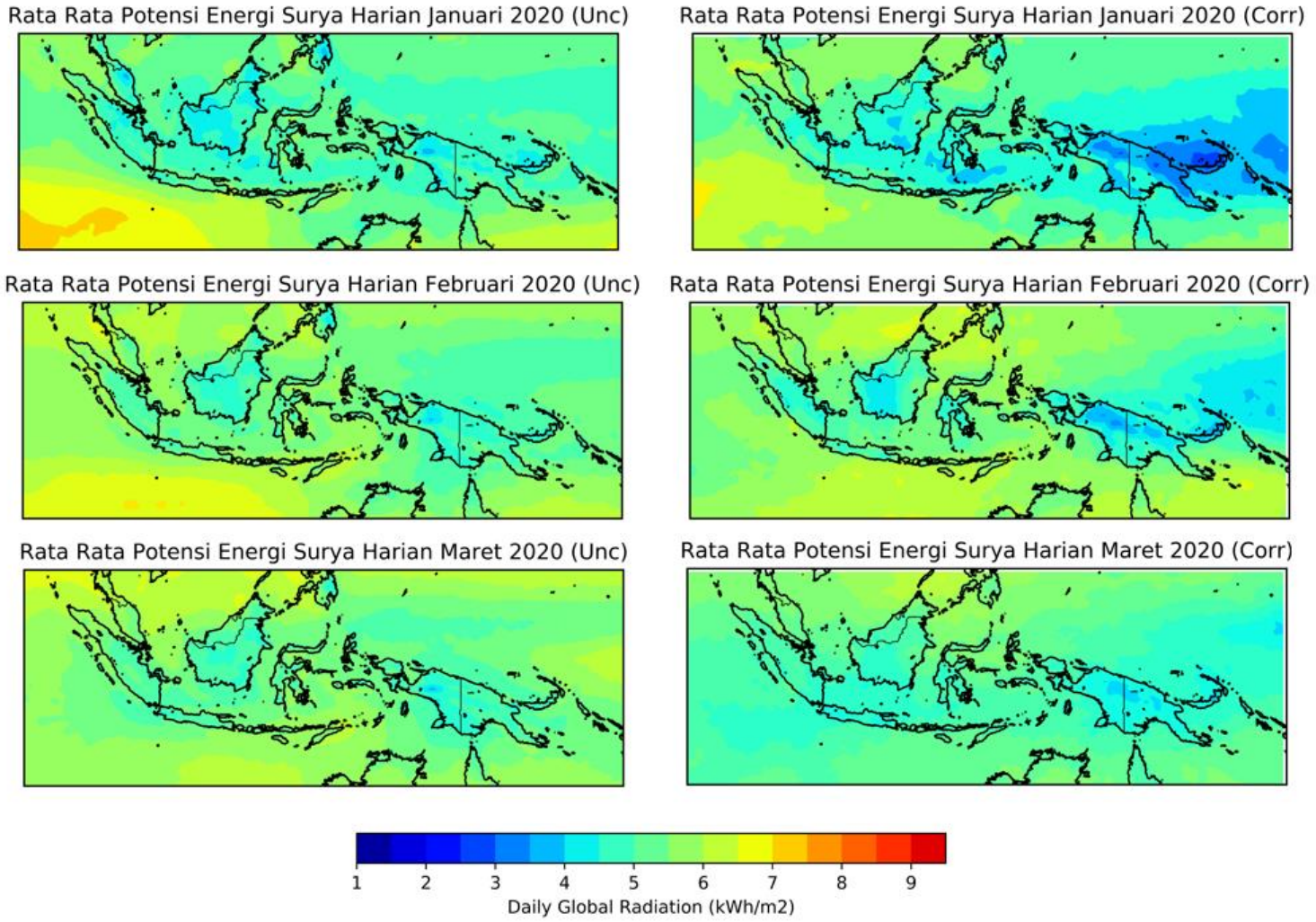
$$\Phi\left(\frac{x-\mu}{\sigma}\right) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right]$$

$$(2\Phi(x) - 1) = \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)$$

➡ The CDF difference is calculated by finding the inverse of the error function

Bias-correction process

- Results of the bias-correction process – left graphs are the uncorrected forecasts and right ones are the corrected.



Validation of the solar radiation forecast

$$\alpha = \frac{\overline{x_{corr}} - Obs}{|\overline{x_{mod}} - Obs|}$$

$$\beta = \frac{\sigma_{corr}}{\sigma_{mod}}$$

- α and β represent mean error ratio and standard deviation ratio
- Despite some outliers, the α value in all stations is located between -1 and 1 for most initial running time and lead time.
- The bias correction technique did not necessarily reduce the spread of the forecast.