PO.182

Climatological attribution of wind ramp events and their probabilistic forecast based on self-organizing maps

Masamichi Ohba, D. Nohara, and S. Kadokura

Central Research Institute of Electric Power Industry

CRIEPI Central Research Institute of Electric Power Industry
Environmental Science Research Laboratory

Abstract with introduction

✓ Energy policy and status of renewable energy in Japan was dramatically altered after the Fukushima Nuclear Plant Accident in early 2011 (e.g., Mizuno 2014) and the total production of wind power in Japan will be significantly increased in recent decades. The greatest problem with this energy source is its fluctuations that can lead to unexpected rapid large increases and decreases in power output in a short period, which are known as wind ramp events (e.g., Marquis et al., 2011). Since the wind ramp events increase instability of the power grid and must be balanced by other power sources, the forecast of the magnitude and timing of ramp events can significantly supports grid operators.

✓ We present an application of self-organizing maps (SOMs) for climatological/meteorological study and probabilistic forecast of the wind power ramp events. To analyze and connect the relationship between atmospheric synoptic patterns over Japan and wind power generation, SOM is employed on sea level pressure derived from the JRA-55 reanalysis over the target area (Tohoku region in Japan), whereby a two-dimensional lattice of weather patterns (WPs) classified during the 1977–2013 period is obtained. To compare with the atmospheric data, the long-term wind power generation is reconstructed by using a high-resolution surface observation network AMeDAS in Japan.

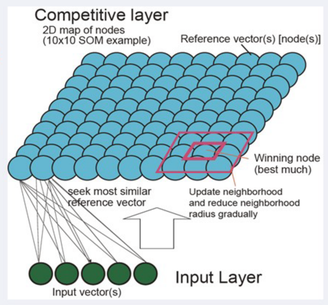
✓ The wind-power ramp events (defined as a 30% change in power in less than 6 hour) are mainly emanating in the winter months in the East Japan. Our SOM analysis for the WP in boreal winter extracts seven typical WPs, which are linked to frequent occurrences of wind ramp events. The result highlights the importance of changes in the WPs to both the wind power generation and ramp frequency in Japan. These findings have important implications for the use of weather/climate forecasts to estimate the probability of future wind power variability. This study suggests that a detailed classification of the synoptic circulation patterns can be a useful tool for first-order approximation of both the wind power generation and its variability. Further research into the links between weather/climate variability and wind power generation is both necessary and valuable in the East Asia.

Data and method

Data
- ✓ Atmospheric reanalysis : JRA-55 (Ebita et al. 2011; Kobayashi et al. 2015): 0.5 degree: FY1977-2012
- ✓ 3 hour momentary value of sea-level pressure (SLP)
- ✓ Regionally integrated wind power generation in the Tohoku region for FY2012
- ✓ 1-hour value of the wind velocity and sunshine duration of the AMeDAS (meteorological observation station)
- ✓ Ramp definition: wind power variation that produces **>30% change in PU over a period ≤ 6 hours**.
- ✓ The positive (negative) quick change in the PU is represented as "ramp up (ramp down)".

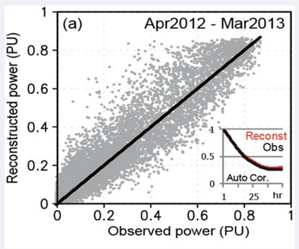
Self-organizing maps (SOM) technique

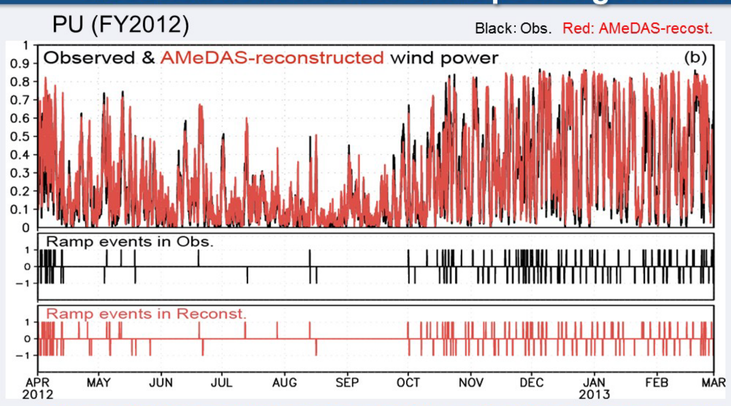
✓ SOM extracts patterns in the anomaly field and projects the extracted patterns on regularly arranged two-dimensional arrays. Each of the arrays on the SOM is denoted as a node (reference vector). 200 reference vectors are presented on the SOM if the map is composed of 200 nodes (e.g., 20 x 20 SOM). The reference vector has the same dimension as the input vector and represents a generalized pattern of input vectors.
✓ Reference vectors that are located relatively nearby (distantly) on the map exhibit a similar (dissimilar) representative pattern.
✓ Each input vector will be compared with all reference vectors and assigned to the node to which the most similar reference vector belongs.
✓SOM classifies input data into the two-dimensional plane utilizing the similarity with the extracted patterns (reference vectors) on the map.
✓Torus SOM (Ito et al. 2000)



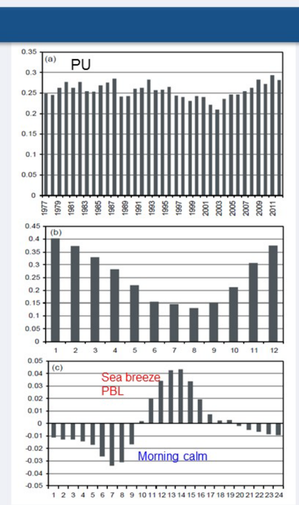
Reconstruction of the wind power generation

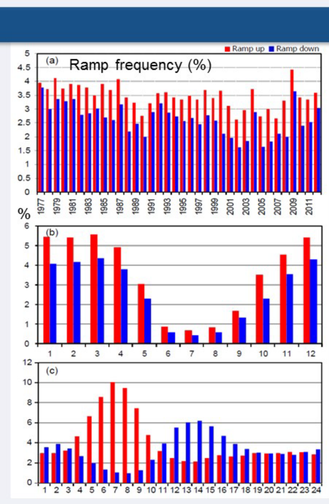
✓ The regionally-integrated rated wind power (Per Unit, PU) in the Tohoku region are reconstructed by the 1-hour value of the wind velocity and sunshine duration of the AMeDAS.
✓15 stations are selected based on the continuity of data that also show relatively high correlation between the observed wind velocity and the PU value.
✓ The empirical equation is a cubic function of two variables (wind velocity and sunshine duration) obtained from the relationship between the station mean and wind power generation.
✓The reconstructed PU values here are considered as an alternative index of wind velocity without artificial influence.





⇒ The attribution analysis and probability estimation of ramp events based on long-term atmospheric reanalysis are available.



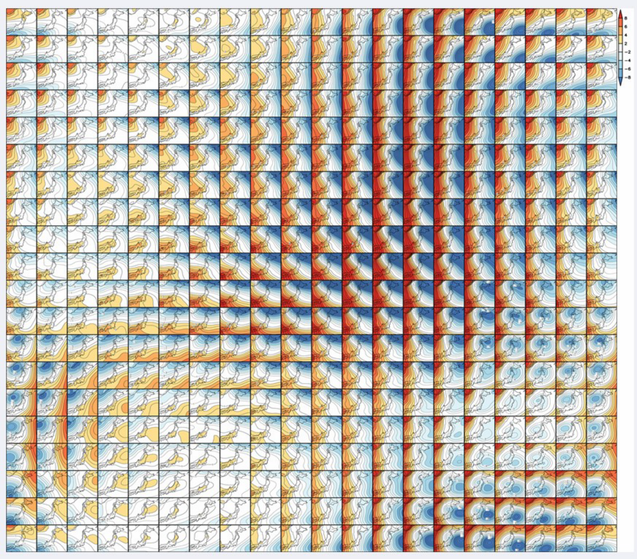


Interannual variation:
relatively strong variability on interannual time scales

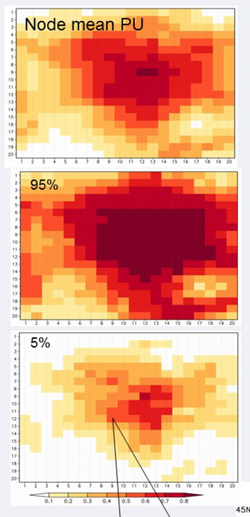
Seasonal variation
Strong at winter to spring

Diurnal variation :
Moring: High ramp up rate
Afternoon: High ramp down

Wind ramp events in Japan

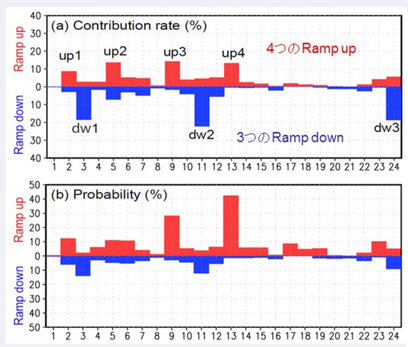


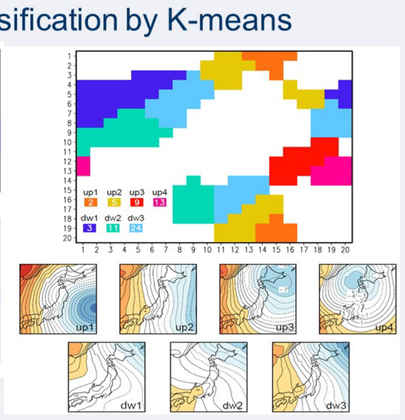
East Japan: DJF 1977-2013
3hr, SLP (diff. from regional mean)
20x20 SOM



Strong contrast is seen among the nodes through the figure.

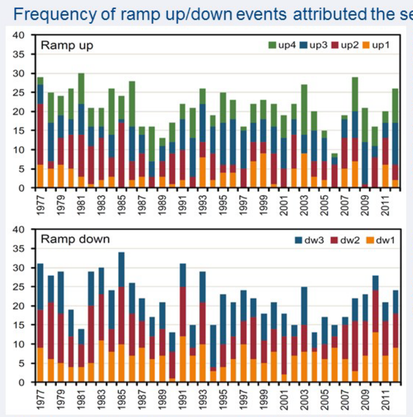
20x20 SOM >> Classification by K-means





Pick up 7 ramp-related clusters!
(high contribution rate and probability)

Frequency of ramp up/down events attributed the seven WP clusters.

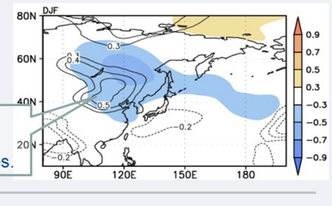


Ramp up frequency
The interannual variation of the total ramp up events is mainly attribute to the up4 that show the relatively largest interannual variation in the clusters. up3 plays a secondary role in the total variation.

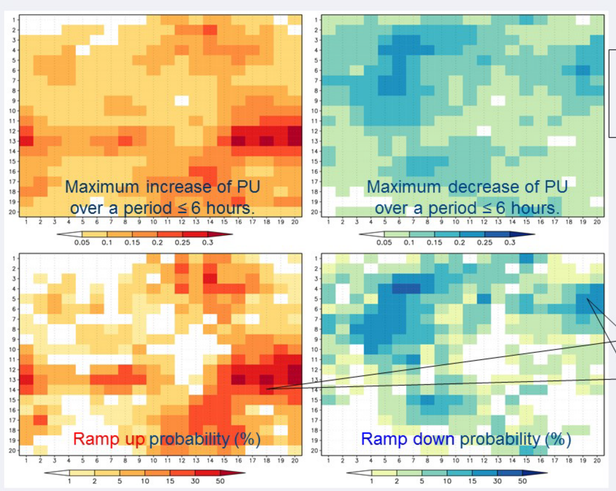
Ramp down frequency
The variation of the ramp down is primarily attributed to the cluster dw2 and secondary to dw3.

The frequency of ramp events associated with up3+up4 and dw3 are weekly but significantly correlated with Arctic Oscillation (AO) index (-0.33 and -0.36, respectively)

Correlation coefficient of monthly mean 500-hPa geopotential height (shade) and standard deviation of the day-by-day 500-hPaGH (contour) to the number of ramp events for December-January-February during 1977–2013.

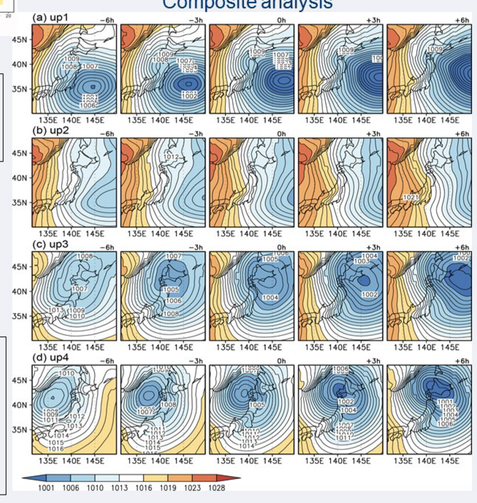


Intensified cyclogenesis with the anomalous low condition implying the ramp events can be highly correlated with the occurrence of extratropical cyclones.



The nodes which have a higher occurrence rate of the ramp events are concentrating on some regions (groups) separately on the SOM.

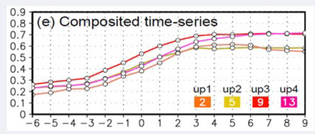
Composite analysis



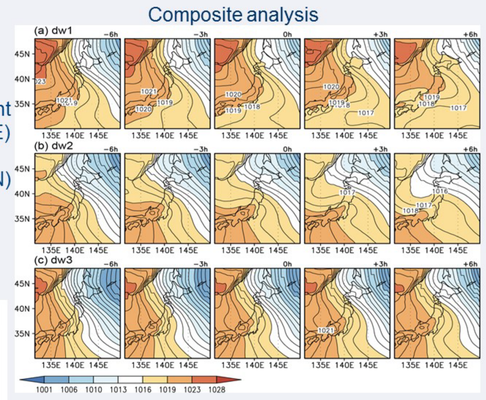
Ramp up clusters

Composited SLP (hPa)
in relation to the ramp-up events

up1) Southeast coast cyclones
up2) Enhanced east-west gradient
up3) Japan Sea cyclones (W -> E)
➢ Zonal SLP gradient
up4) Japan Sea cyclones (W -> N)
➢ Meridional SLP gradient



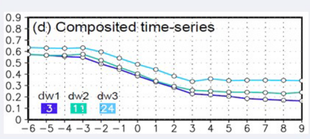
Composite analysis



Ramp down clusters

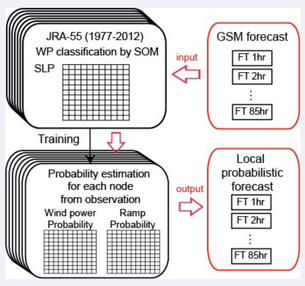
Composited SLP (hPa)
in relation to the ramp-down events

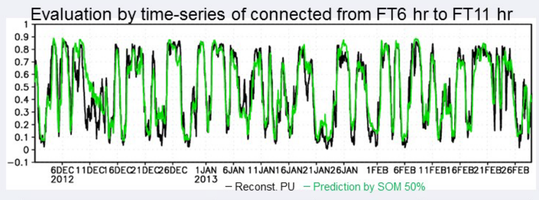
dw1) Siberian-high pressure
dw2) Decreased meridional gradients
dw3) Decreased zonal gradients
In relation to the cyclone pass



Applications for probabilistic forecasting (Multi-Analog Ensemble: MuAnEn)

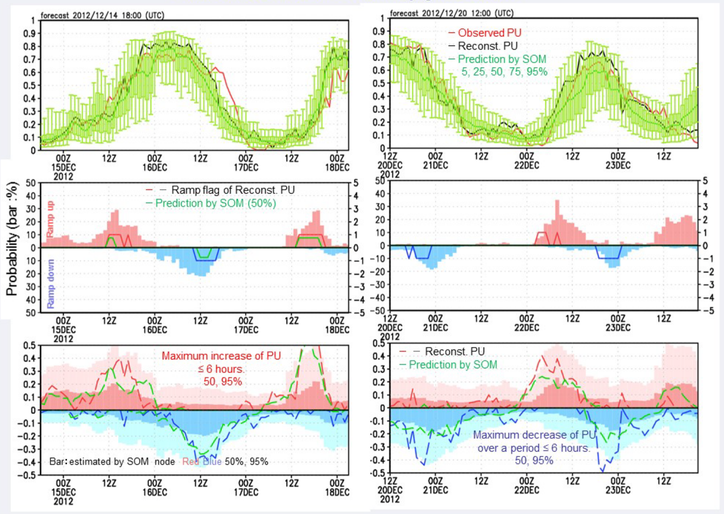
✓ WP(weather pattern)-PU linkage by SOM
> Weather guidance (Perfect-prognosis) as analog method
> Estimate probability of PU, Ramp-up/down, Maximum increase/decrease
✓ Forecast data: JMA GSM-GPV (every 6hr, FT1-85hr by1hr, SLP)
> WP matching and estimate PDF regarded as analog ensemble (DelleMonache et al. 2013) by SOM
> Multiple (7) analogs are used（multi-analog: 20-50x20-50 SOM）



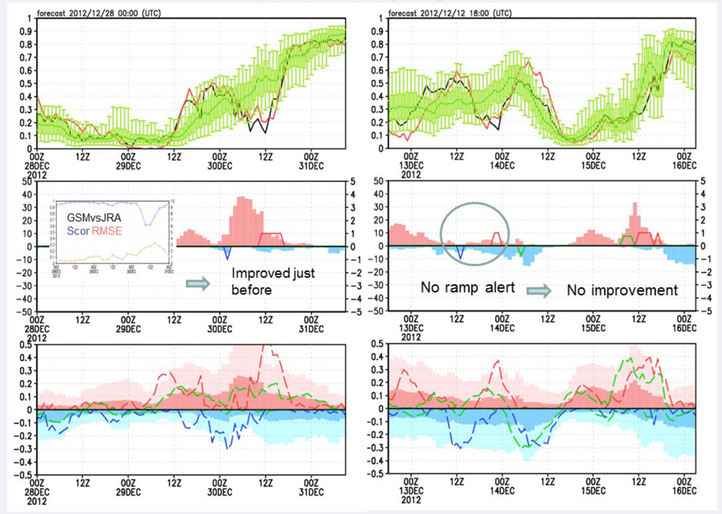


01dec2012-28feb2013	ME(%)	MAE(%)	RMSE(%)
v.s. reconstPU	0.001	8.1	10.8
v.s. ObsPU	-0.04	10.1	12.8

Probabilistic forecast : relatively good case…



Probabilistic forecast : relatively not good case…



The observed PU tend to be included in general in forecasted 5-95%
However, the local scale phenomenon could also be affect the PU that cannot caught at SLP fields, such as PBL change in the mornings and evenings.
➢We should include additional variables ? (e.g., Total amount of cloud and surface radiation)

Acknowledgements

This research is supported by "Power system output fluctuation corresponding technology research and development projects" of the New Energy and Industrial Technology Development Organization (NEDO). The observed PU values are provided from Institute of Industrial Science, the University of Tokyo.

EWEA 2015 PARIS
EUROPE'S PREMIER WIND ENERGY EVENT

EWEA 2015 – Paris – 17-20 November 2015