Impact of orographically-induced winds to the offshore wind resource around northern Japan

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Wind resource assessments have shown high potential for wind energy in northern Japan. In regions where large wind resources are estimated, previous studies suggest that orographically-induced winds often occur. However, more observational studies are necessary to obtain detailed pictures of the orographically-induced winds and understanding of generation mechanism is required. With an increase in development of offshore wind energy and installation of offshore wind power plants, meteorological studies are increasingly required to estimate offshore wind resource, to understand the variation in the wind energy, and to predict the wind power output. Therefore, this study presents the orographically-induced winds around northern Japan and their occurrence mechanisms, and discusses contribution of the orographically-induced winds to regional wind resource.

Keywords: offshore wind, wind energy, northern Japan, satellite observation

Estimation of photovoltaics power generation in consideration of both its installed capacity and satellite-estimated solar irradiance

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Recently, in Japan, large photovoltaics (PV) power systems have been penetrated after feed-in-tariff (FIT) in 2012. PV power generations have large variability in both temporal and spatial scales beacause PV power depended on solar irradiance (or downward shortwave radiation). Solar irradiance has also impact from both clouds and aerosols distributions.

PV power generation from roof-top PV power system on residences, industrial manufactures and small-, mediam- and large-scale solar plants have not directly been monitored even by electrical power companies in Japan because monitorying instruments have not been installed even in distributing substations and residences. This is a problematic situation for safty control of electric power grid, because accurate PV power generation from PV power system under various weather conditions were not grasped. Accurate monitoring of PV power generation could be important data for a safety electric power control of power grid in energy management system.

Thus, PV power generation estimation using satellite-estimated solar irradiance data in consideration of PV syetem capacity for city-wide scale are conducted in Japan in this study for the first time. Furthermore, installed PV power system capacity for each area and future status of PV power will be also discussed.

Keywords: photovoltaics power generation, Meteorological satellite, PV power estimation

Evaluation of Cloud locations with Stereo Observations for predicting solar PV temporal variation

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Photovoltaic (PV) power generation is one of important renewable energy, and it has been getting more poplar and numbers of both mega-solar PV and small scale solar PV systems have been rapidly increasing these days. While the solar PV is a common renewable energy source, it is difficult to predict temporal variation of power generation accurately depending on weather conditions. Especially it has been reported that passing of patchy clouds makes the prediction more difficult (Itagaki et al., 2011, 2012). The difficulty is from both weather forecast and observation issues. Because the grid interval of current weather forecasting is the order of 1 km, it has not been able to resolve sub-km scale cloud distributions which can affect variation of local solar PV power generation. The typical spatial resolution of geostationary satellites, such as Himawari-8, is 500m - 1km size, which is also not enough to resolve the small-scale cloud structures.
To have better spatial resolution for cloud observation, we have planned to develop a cloud monitoring system constructed with multi (more than three) wide field of view (FOV) cameras, the interval of each camera is a few hundred meters. The interval allow us to measure cloud locations with a stereo estimation method for the clouds from several km to ten km altitudes. In addition, current wide FOV cameras allow to resolve cloud position with a smaller resolution than 100m.
In this study, to demonstrate the stereo measurement can work for clouds at the first step, we set two cameras with ~400m interval and took images which satisfied stereo condition for several to ten km altitude clouds. The camera orientation and the amount of tilting were measured with star position measurement in the camera images, which is a common technique for determining a satellite attitude in space with less than 0.1 degree accuracy, and it takes no additional cost. From the stereo measurement, we have successfully resolved cloud positions whose altitudes were from 1,300m –2,500m, and also we have resolved cloud motions from sequential observation images. In this presentation, we will introduce our approach for measuring three dimensional cloud positions and its results, and we will discuss predicting temporal variation of solar PV power generation with the cloud positions and the cloud motions.

Keywords: Solar photovoltaic power generation, Stereo measurement, Clouds

Detection of forecast busts of regional surface solar radiation using ensemble spread with multi numerical weather prediction centers

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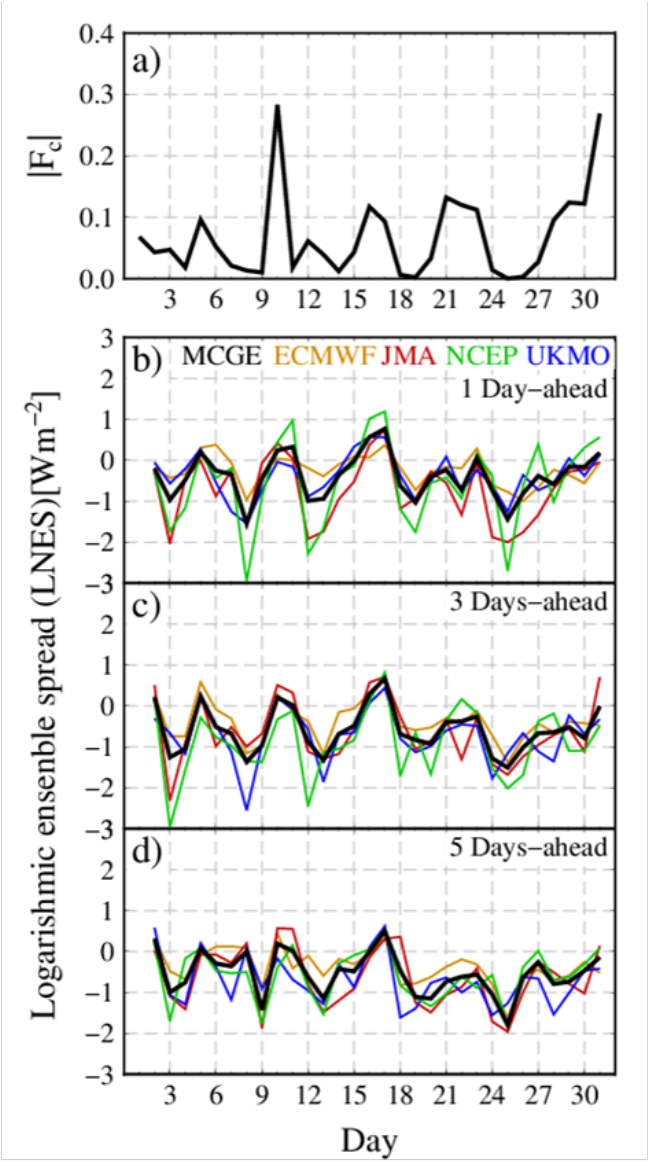
Energy management using weather forecast of numerical weather prediction (NWP) center is exposed to blackout risks and production of excessive surplus power owing to the large forecast errors (forecast busts) of NWP models. The detection of forecast busts is important for stable electricity provisions. Dispersion of ensemble forecast (ensemble spread: ES) relate to forecast skill. Multi-center grand ensemble (MCGE) has higher forecast skill than single-NWP center ensemble forecast. It is considered that the ES and ES of MCGE (ES_g) can be used as the predictor of the forecast busts. We investigate the detectability of forecast busts on operational regional forecast predicted by Japan Meteorological Agency (JMA-MSM) using lognormal ES (LNES) and ES of MCGE ($LNES_g$) in Kanto Plain, Japan. One- to six-day ahead global forecast at four leading NWP centers (European Centre for Medium-Range Weather Forecasts: ECMWF, Japan Meteorological Agency: JMA, National Centers for Environmental Prediction: NCEP, and Met Office, UKMO) were used to detect of daily surface solar radiation of regional forecast in 2015.

Root mean square error for the ensemble mean of MCGE (EM_g) and 5km regional forecast of JMA-MSM are 27.6 and 28.6 Wm^{-2} for the one-day ahead forecast, respectively. The forecast skill of the EM_g was found to be comparable with that of the JMA-MSM. In October 2015, the correlation between the absolute value of forecast error coefficient (|Fc|) on the operational regional forecast and $LNES_g$ for the one-, three-, and five-day ahead forecasts are 0.68, 0.63, and 0.45, respectively (see Figure). The correlation for one- and six-day ahead forecast was found to have statistical significance at ten and seven months, respectively. The $LNES_g$ can be, therefore, a valuable predictor for detection of forecast busts in the regional forecast.

Keywords: Ensemble forecast, Forecast busts, TIGGE, Surface solar radiation



Figure, Time series of Fc in JMA-MSM and ensemble spread in October 2015. (a) |Fc| in JMA-MSM one day-ahead forecast, and (b, c, d) LNES and $LNES_g$. in one (b), three (c), and five (d) day-ahead forecast. Colored thin lines indicate the LNES each NWP centers as shown in the legend. Thick line indicates $LNES_g$ in MCGE.

Probabilistic Weather Prediction for Power Demand/Supply Operation Management under the High Penetration of Renewable Energy Power

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Renewable energy power, such as from photovoltaics and wind, is volatile partly because of natural variability in weather conditions. Electric power companies have to manage the balance between supply and demand. Management of the volatility of renewable energy power is a key factor in minimizing the cost of integrating renewable energy power into electric grid systems while maintaining the required high level of reliability. For this purpose, probabilistic weather prediction for renewable energy power is one of the most cost-effective and easily implemented tools available to system operators.
In this study, we developed a regional ensemble prediction method using the Weather Research and Forecasting (WRF) model to a predict probabilistic weather. To obtain dynamically consistent perturbations with a synoptic weather pattern, both initial and lateral boundary perturbations were determined via differences between the control and an ensemble member of the Japan Meteorological Agency (JMA)'s operational one-week ensemble forecast. This method provides multiple ensemble members for Japan area with a horizontal resolution of 15 km for 75 hours at 30-minute interval outputs by downscaling the JMA's operational global forecast along with the perturbations. The predictions were able to represent various features of the high-resolution spatiotemporal distribution of precipitation affected by the intensity and location of extratropical cyclones in each ensemble member. Although the ensemble prediction method showed model bias in the mean values and variances for certain variables such as irradiance or wind speed, it has the potential to provide probabilistic information regarding the uncertainty of weather prediction.

Keywords: Renewable energy, probabilistic prediction, ensemble

Study on the freezer system with solar energy source

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Many countries started to use renewable energy resource as an alternative energy source for electricity production because of environmental issues such as global warming and greenhouse gas concentration as a result of burning fossil fuels. Out of 5 main renewable energy resources, solar energy utilization is constantly increasing because of its mature technology and equally distributed resource throughout the world. Therefore, solar energy is used in many fields and in this study, photovoltaic system performance for meat freezer in rural areas of Mongolia is investigated. The main facilities are movable freezing container, grid connected 3kW photovoltaic modules, inverter, diesel generator and data logger to measure the parameters of this system. Starting from November 2015, we collected a year round site measurement which includes solar irradiation, outside and inside temperature of the container, electricity production and consumption. We use HOMER software to calculate the energy production by photovoltaic system and energy consumption of freezer system. Then, we compared this calculation with the real value and calculated the solar energy share of total electricity consumption. Also, we modeled an E-nose to monitor the freshness of meat preserved in the freezer. The result suggests that it is suitable to use photovoltaic system for meat storage in rural areas where grid electricity interrupts often.

Keywords: solar energy, photovoltaic system, freezing system

Derivation of time series of the sky-cloud ratio from omnidirectional camera images for predicting sky conditions

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Prediction of photovoltaic output is necessary to efficiently control photovoltaic systems. In order to make a prediction about the output, it is necessary to predict the variations of the sky conditions. Therefore, the purpose of this study is to prepare a system that can always continue to take sky images using an omnidirectional camera, and to develop algorithms for calculating the time series of the sky ratio. First, we take sky images once every minute by the camera and store them as JPEG images. Next, we train a classifier using R and B of some images. Finally, we calculate the sky ratio of images, which we did not use for the training, using the classifier. F-measure in the cases of cloudy day is >0.9 and that in the cases of clear day is approximately 0.9 at daytime. Although F-measure tends to decrease drastically in the images with dark sky at dawn and evening, we are able to extract variations in sky ratio over the observation period, especially accurately in cloudy and mostly sunny days.

Keywords: Photovoltaic generation, All-sky images

Climatological attribution of wind power ramp events in East Japan and their probabilistic forecast based on multi-model ensembles

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This study presents an application of self-organizing maps (SOM) for the climatological/meteorological study of wind power ramp events. SOM constitutes an automatic data-mining clustering technique, which allows for summarizing of a high-dimensional data space in terms of a set of reference vectors. SOM is applied to analyze and establish the relationship between atmospheric synoptic patterns over Japan and an object e.g., wind power generation. In this study, synoptic patterns derived from the JRA-55 reanalysis over the Tohoku region in Japan are classified by using SOM into a two-dimensional lattice of patterns. Wind-power ramp events (defined as a 30% change in power in less than 6 h) mainly take place during the winter months in East Japan. Our SOM analysis for weather patterns in boreal winter extracts seven typical patterns that are linked to frequent occurrences of wind ramp events.
Medium-range probabilistic wind power prediction is derived by this SOM lattices based on the weather patterns of the multi-center grand ensemble forecasts for a particular day. Because this analog approach effectively handles the stochastic uncertainties indicated by the large number of ensemble members, a probabilistic wind power generation is easily and quickly obtained from the huge number of ensemble forecasts. The use of multi-center grand ensemble forecasts provides results better than those from one forecast model. The predictability skill of the forecasts for the wind power generation and ramp events show the relatively good skill score under the downscaling technique. It is expected that the results of this study provides better guidance to the user community and contribute to future development of system operation model for the transmission grid operator. The advantage of this method is it can include the interpretative analysis of the impact of meteorological/climatological factors on the variation of the renewable energy.

Keywords: Wind power, Ramp events, Self-organizing maps, Weather patterns, Synoptic climatology, Renewable energy

Evaluation of shallow groundwater quality for use in open-loop type groundwater-based heat pump system

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In cold snowy regions, kerosene is used as fuel to melt snow in the winter, but geothermal heat is more suitable in terms of suppressing greenhouse gas emissions. Regarding shallow geothermal heat utilization heat pump systems, there are closed-loop and open-loop systems. In a closed-loop system, a high initial cost is required for installation of the underground heat exchanger, but in the case of the open-loop system using the shallow groundwater, the initial cost can be suppressed as compared with the case of the conventional method. Therefore, we think it is important to promote open-loop systems using shallow groundwater. However, in floodplains and deltas excluding alluvial fans used as farmlands and residential lots, shallow groundwater may contain a large amount of iron and free carbonic acid, which may affect the use of heat pumps. In particular, it is not clear whether the free carbonate concentration is constant in shallow groundwater or variable, greatly or otherwise. Therefore, in this study, we aimed to clarify the fluctuation characteristics of several water quality parameters, especially free carbonate concentration, in shallow groundwater. For almost one year, groundwater was monthly collected from three depths of about 3 m, 8 m, and 18 m in the downstream area of the Tsugaru plain of the Aseishi River in Aomori Prefecture. At the time of collection, pH, electrical conductivity, and water temperature were measured in the field. Concentrations of Na^{+}, NH_4^{+}, K^{+}, Mg^{2+}, Ca^{2+}, F^{-}, Cl^{-}, Br^{-}, NO_3^{-} SO_4^{2-}, Fe, Mn, Sr, Ba, Si, and alkalinity were analyzed. Using the measurement results from such, the free carbonate concentration was determined using the aqueous geochemical calculation computer program PHREEQC. The free carbonate concentration fluctuated, with a range of approximately 50 to 100 mg/L of groundwater at a depth of 3 m, about 40 to 80 mg/L at a depth of 8 m, and approximately 10 to 30 mg/L at a depth of 18 m. This is possibly due to the fact that the influence of events occurring on the ground surface decreases with an increase in depth.

Keywords: open-loop type groundwater-based heat pump system, shallow groundwater, water quality

